PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION.

Engineering Library

# ENGINEERING:

An Illustrated Weekly Journal

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

TEMPORARY OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 18 & 20, COMPTON ROAD, HAYES, MIDDLESEX.

VOL. 149—No. 3860. LONDON: FRIDAY, JANUARY 5, 1940. Registered at the General Post Office as a Newspaper PRICE 1s. BY FOREIGN POST 1s. 2½d.

JAN 30 1940

S.E.A. RINGS AND SYNTHA PACKINGS 683
LONG LIFE WITH LOW FRICTION
RONALD TRIST & CO. LTD.
BATH ROAD, SLOUGH

INFINITELY BETTER
SPRINGS
SUPER GRADE SPRINGS OF EVERY DESCRIPTION FOR EVERY PURPOSE
On Admiralty, War Office, and Air Ministry Lists. Established 1821.
ROBERT RILEY LTD. 9989
Milkstone Spring Works, Rochdale. Tel. 2572

J. & E. Hall, Ltd.
ENGINEERS, DARTFORD, KENT. Est. 1785
Telephone: Dartford 3456
London Office: 10, St. Swithins Lane, E.C.4.
Telephone: Mansion House 9811.
REFRIGERATION FOR LAND AND MARINE PURPOSES
LIFTS AND ESCALATORS 755

DYSON TRAILERS
R. A. DYSON & CO., LTD.,
GRAFTON STREET, LIVERPOOL 785
Models to carry from 3 cwts. to 150 tons.

ALL TYPES OF
COLLARS
ALL SIZES. LARGE STOCKS.
H. FORDSMITH LTD.,
Hadfield Street Works, Cornbrook, MANCHESTER, 16.
TRAfford Park 0789 793

GLASS For Machinery
BUTTERWORTH BROS., LTD., 9753
Newton Heath Glass Works, Manchester.

DANIELS
FOR
PLATENS
STEAM, GAS OR ELECTRIC
T. H. & J. DANIELS LTD.
STROUD, GLOS. Phone: 661/2/3.

SPENCER - BONECOURT
Patent Waste Heat Boilers
32, Farringdon Street, London, E.C.4. 9817

LOCOMOTIVES
STEAM OR DIESEL
HUDSWELL CLARKE & Co. Ltd.
RAILWAY FOUNDRY, LEEDS.
London Office: 46, Victoria St., S.W.1.
Telephone: Victoria 1133 8559

YARROW
& CO. LTD.,
GLASGOW
SHIPBUILDERS
MARINE ENGINEERS 9846
LAND AND MARINE BOILER MAKERS

CRADLEY BOILERS
CRADLEY BOILER CO., LTD., 639
CRADLEY HEATH, STAFFS.

PETER BROTHERHOOD
PETERBOROUGH LTD.
STEAM ENGINES AND TURBINES,
GAS AND OIL ENGINES,
AIR COMPRESSORS,
REFRIGERATING PLANT,
See advertisement, Page 29, Dec. 15. 6938

FRICTION CLUTCHES
All Types. Satisfaction Guaranteed.
W. R. ANDERTON & CO.,
Clutch Specialists,
CASTLETON, ROCHDALE 506

CRANES
GEORGE RUSSELL & CO., LTD.,
Motherwell. 9814

DREDGERS
OF ALL TYPES
FERGUSON BROS. (Port-Glasgow) LTD.
PORT-GLASGOW 629

GEARING
BARRY, HENRY & COOK, LTD.
789

PLENTY
& SON LIMITED, NEWBURY
MARINE ENGINEERS.
STEAM ENGINES
TO 1500 I.H.P. 597
FOR ALL CLASSES OF VESSELS
STERN GEARS
FOR DIESEL MOTOR VESSELS AND COMPLETE INSTALLATIONS UNDERTAKEN.
COX PATENT ROTARY DISPLACEMENT PUMP

SPECIAL MACHINES
MADE TO ORDER
Parts and repairs
Erection of plant
Millwrights work 9963
THOMAS HUNT & SONS
Bridge Road West BATTERSEA, S.W.11.

BABCOCK

RAPIER
WALKING DRAGLINES
RANSOMES & RAPIER LTD.
Ipswich England 548
Builders of Europe's Largest
EXCAVATORS

BAXTERS
"PATENTED KNAPPING MOTION"
STONEBREAKERS
and ALLIED SPECIALITIES 756
W. H. BAXTER, Ltd., Leeds, 12.

PRODUCTION ENGINEERING AND PRECISION MACHINE TOOL WORK
OF THE HIGHEST STANDARD.
PLEASE WRITE TO US REGARDING YOUR URGENT WORK
W. W. GARDNER LTD.,
CONTRACTORS,
48, WOBURN PLACE, RUSSELL SQUARE, LONDON, W.C.1. J 701

MACROME
—Toughest Tools in the World—
9934
MACROME LTD.
Hay Mills, Birmingham. Telephone: Vic. 1283

MUREX
Electrodes
625
MUREX WELDING PROCESSES LTD.,
HERTFORD RD., WALTHAM CROSS, HERTS.

ELECTRIC
CONTROL GEAR
VLASTO, CLARK & WATSON
STOCKTON HEATH, WARRINGTON 739

Engineering Works solicit ENQUIRIES for JIG and PRESS TOOL WORK up to 12 by 12. Also some capacity for 6-in. Hollow Spindle, Centre Lathe, Turret Lathes, External and Internal Grinders, Horizontal Boring Mill, etc. Immediate delivery.—Address, J 702 Offices of ENGINEERING.

Research Engineers, Ltd., Northampton Grove, Canonbury, London, N.1. Design and construction of mechanical and electrical machinery and apparatus. Experimental work of any description. We specialise in the construction and testing of internal combustion engines of new design. Certified reports of tests supplied. 794

VALVE
9796

MOSS
A name of fame for highest quality machine cut
GEARS
THE MOSS GEAR CO. LTD.
Crown Works, Tyburn, Birmingham. 8041

Send for NEW Catalogue
COOPER
SPLIT
ROLLER BEARINGS
KING'S LYNN 708 NORFOLK

SAND FILTERS
JOHN THOMPSON
(KENNICOTT WATER SOFTENERS) LTD.,
WOLVERHAMPTON
Estd. over 40 Years 744

"The machine with a BRAIN"
SCIAKY
SPOT WELDERS
SLOUGH —— 22342

LA MONT
WASTE-HEAT BOILERS
Particulars from:— 677
LAMONT STEAM GENERATOR LTD.
Quadrant House, 55, Pall Mall, London, S.W.1.

TUBES LTD.
ASTON, BIRMINGHAM.
Manufacturers of 9857
WELDLESS STEEL BOILER TUBES · COLD DRAWN TUBES
FOR THE ENGINEERING INDUSTRY

ALLDAYS & ONIONS
See Page 17 BIRMINGHAM. LTD.
HAMMERS PNEUMATIC & STEAM

PISTON RINGS
HARRY LANCASTER & CO. LTD.
1/3, BRIXTON ROAD, LONDON, S.W.9.

"DELTA" BRAND NON-FERROUS METALS AND ALLOYS
THE DELTA METAL CO. LTD.
LONDON and BIRMINGHAM

VALUE

# 50% REDUCTION IN TOOL COSTS

*TWO SPECIALITIES:*

## MACROME TREATED

## SCREWING DIES

FOR COVENTRY AND HERBERT DIEHEADS

## and S.K.F. TAPS

*MACROME TREATMENT TOUGHENS AND YOU MAY INCREASE FEEDS AND SPEEDS*

**ALL TYPES OF CUTTING TOOLS EX STOCK**

# MACROME

## LIMITED

*Works and Registered Offices:* **HAY MILLS, BIRMINGHAM**
Tel. No.: VIC. 1283

*Manchester Offices:* **62, MARKET STREET**
Tel. No.: BLACKFRIARS 1324

*London Offices:* **3, GROSVENOR GARDENS, S.W.1**
Tel. No.: VIC. 4845

JAN. 5, 1940. VOL. 149.

# ENGINEERING.

## LOAD TESTS OF A 4,000-KW. COMBUSTION-TURBINE SET.

By Professor Dr. A. Stodola.

The unit of which the test results are given below is a gas-turbine set built by Messrs. Brown, Boveri and Company, Limited, of Baden, Switzerland, comprising a combustion turbine and consisting only of the essential components, such as compressor, combustion chamber, turbine exhausting directly to atmosphere, and generator. The deliberate omission of any additional refinement, such, for example, as a heat exchanger between the exhaust gases and the combustion air, is justified by the fact that the turbine is intended for a bomb-proof plant which will be in service only a few hours per annum, so that an increase in cost for the purpose of raising the efficiency would not be economical. In spite of the simplicity of the arrangement, the tests showed the efficiency, referred to the heat contained in the fuel and the heat equivalent of the electrical output of the generator, to be 17·38 per cent., representing an efficiency which, together with the numerous constructional advantages of the set, renders it in many cases competitive. A feature specially worthy of note is the fact that the plant requires no cooling water.

The present-day possibilities of realising a successful gas turbine, resulting from the improvement of the compressor efficiency on the one hand, and the availability of heat-resisting materials on the other, would have appeared unthinkable but a short time ago. The axial-type compressor, developed some seven years ago by Messrs. Brown, Boveri in connection with the Velox steam generator, gives an improvement in the performance of the gas-turbine cycle of 65 per cent., compared with the best result attainable with a centrifugal type of compressor, while a further improvement of 18 per cent. is rendered possible by the increase in temperature which can be withstood for a given creep limit by the best heat-resisting steels now produced. Were it not for these developments, the only possibility for the realisation of the gas turbine would be that suggested by Holzwarth in 1905, namely, the explosion cycle, which was subsequently persistently pursued by him, in spite of many sacrifices, until in 1933, in collaboration with Messrs. Brown, Boveri and Company, a working explosion-turbine plant was produced. The encouraging results obtained with this unit led, about 18 months ago, to the placing of an order by the Aug. Thyssen Steel Works, in Hamborn, for a 5,000-kW set. Messrs. Brown, Boveri and Company, during the course of development of the Velox boiler and the supercharging sets, have devoted considerable attention to the scientific investigation of fluid-flow conditions, and to the solution of constructional problems of gas turbines and axial blowers. The result of this development work is seen in the plant described below, the individual efficiencies of the components representing the highest values hitherto achieved.

In the diagrammatic arrangement, Fig. 5, on page 3, *a* is the compressor, which compresses the air to about 40 lb. to 60 lb. per square inch absolute. The drum is secured by shrinking and welding on to the shaft ends. The shape of the inlet passage, as has been shown by model tests, enables the kinetic energy of the gas stream to be converted into pressure. Guide blades give the air entering the combustion chamber *b* a slight rotational motion. Only part of the total air is made use of for combustion, so that the temperature reaches about 2,500 deg. F. The remainder of the air subsequently mixes with the gases after combustion is completed, to bring the temperature down to about 1,000 deg. F. The turbine *c* is provided with multi-stage reaction blading. The starting motor is shown at *d*. The rotor, shown in section in Fig. 6, consists of two shaft ends, each formed in one piece with the end disc, and of an intermediate unbored disc of constant strength section, welded at its periphery to the two outer discs, in accordance with the well-known process of the manufacturer. This process has, apart from the advantage of the unbored disc of constant strength, the additional advantage of doing away with the necessity of shrinking the discs, or of providing keys and keyways required in the case of a continuous shaft, and

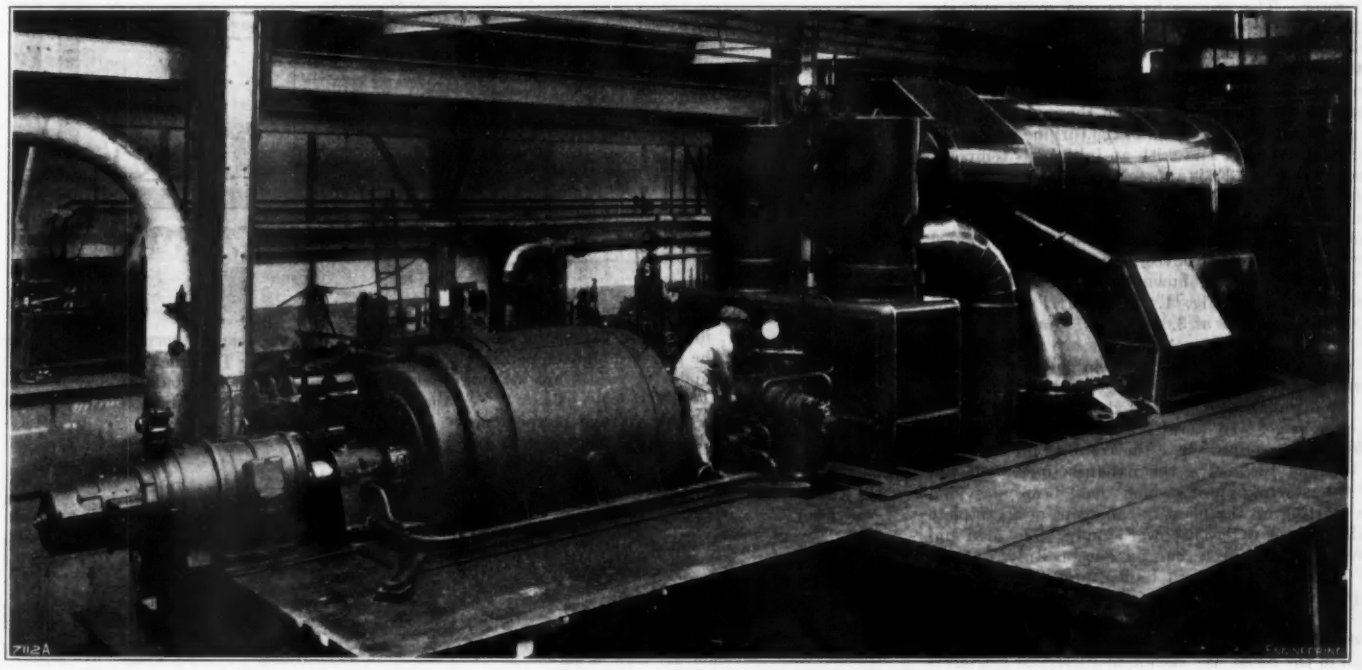


Fig. 1. 4,000-KW. Gas-Turbine Set on Test Bed.

# TESTS OF 4,000-KW. GAS-TURBINE SET.

Fig. 2.

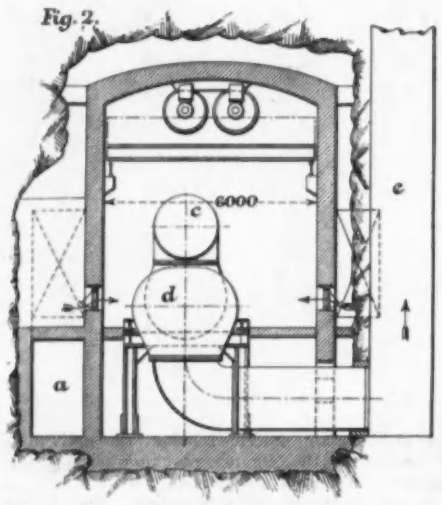



Fig. 3.

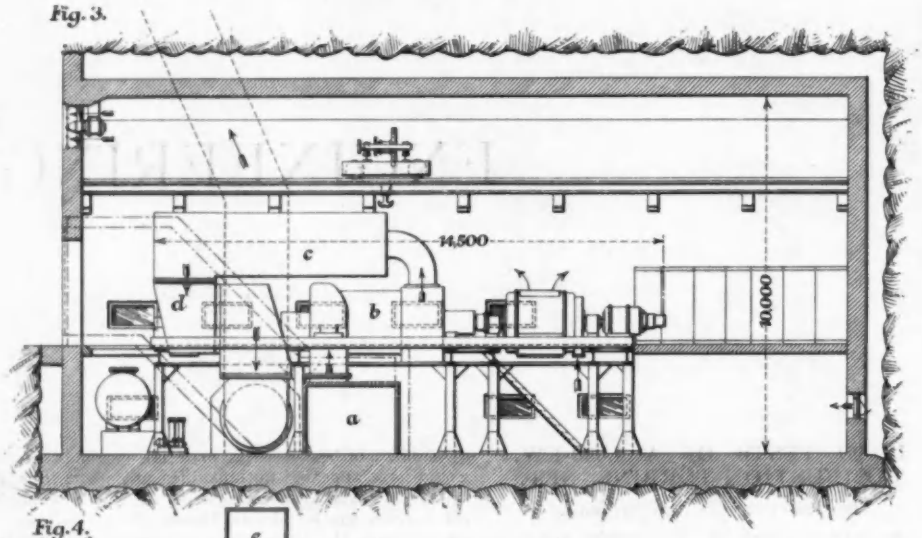
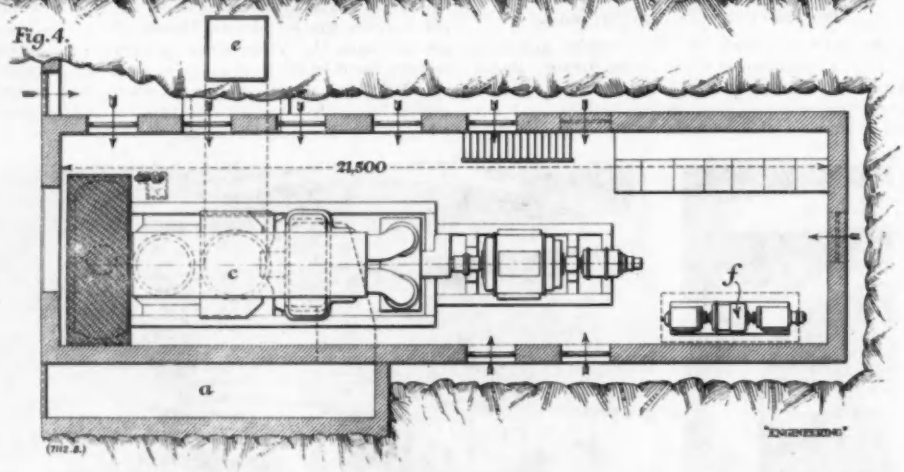



Fig. 4.




which are undesirable where high temperatures are encountered. The rotor is built up of easily forged components and the large distance of the welds from the axis results in very low stresses in the weld material due to bending or possibly vibration of the rotor. The process has proved to be entirely reliable and given excellent results in numerous steam turbines built by the firm. The difference between the axial thrusts of the turbine and the compressor is taken up by means of a common segmental thrust bearing. The thermal expansion on an overall length of 2 m. of the turbine, measured over the bearings, and with an initial gas temperature of 1,000 deg. F., is appreciable, but the difference between the expansions of the casing and the shaft, owing to the insulating effect of the lagging, is quite small. The glands consist of thin alloy-steel strips caulked into grooves in the shaft.

The set, which is shown on the test bed at the Baden works in Fig. 1, on page 1, is rated at 4,000 kW and runs at 3,000 r.p.m., producing three-phase current at 50 cycles for the city of Neuchâtel in emergencies; it is housed in an underground bomb-proof chamber. The general arrangement of the installation is illustrated in Figs. 2, 3 and 4, on this page. In these illustrations, *a* is the air inlet, *b* the compressor, *c* the combustion chamber, *d* the gas turbine, *e* the exhaust duct, and *f* a Diesel starting unit which has been provided for starting up the plant in the event of a complete failure of the external power supply. The load and governing tests were carried out on July 7, 1939, at the maker's works in Baden, under the personal supervision of the writer, and with the assistance of the officially recognised Swiss Association of Steam Boiler Proprietors and of the test laboratory staff of the Swiss Association of Electrical Engineers for the power measurements. The calorific value of the fuel was determined by the Fuels Department of the Swiss Federal Material Testing Laboratories. The fuel consumption was determined by weighing in a large vessel on a calibrated sliding-weight balance, the vessel containing sufficient fuel for more than an hour's run. Readings were taken every ten minutes. The electrical output at the terminals of the three-phase generator was measured by means of a precision kilowatt-hour meter, read every two minutes. The results of the measurements, and the characteristics of the fuel are given in Tables I and II, annexed.

*Efficiency of the Plant.*—In order to obtain, with the ambient temperatures of 77·5 deg. and 78·8 deg. F. prevailing during tests II and III, the same compression and expansion ratios and efficiencies as would obtain with an ambient temperature of 68 deg. F., on which the guarantees were based, the speed was raised during tests II and III from 3,000 r.p.m. to 3,020 r.p.m. and 3,030 r.p.m., respectively. The readings then recorded are given in Table III, opposite. These figures show that the performance of the unit is better than was guaranteed. It is, however, interesting to analyse these results with the aid of the pressure and temperature readings. The more important values are set out in Table IV, on page 4.

In order to determine the average temperature of the products of combustion at the inlet of the gas turbine with greater accuracy than is possible by means of local measurements by thermocouples, measurements of the exhaust gas quantity were made in the preliminary trials by means of a standard nozzle located in the exhaust duct, the nozzle being subsequently removed in order to avoid any unfavourable effect on the efficiency from the additional pressure drop. The air quantity delivered by the compressor was then obtained by deduction from the total gas quantity of the weight of the fuel, thus enabling the speed-volume characteristic of the compressor to be drawn. For the gas turbine, the following approximate flow formula was employed:

$$G = C \cdot \frac{p_1}{\sqrt{T_1}} \sqrt{1 - \left(\frac{p_2}{p_1}\right)^2}$$

the constant factor being determined by means of a calibrated nozzle. The inlet temperature was then derived from the heat-balance equation of the combustion chamber, radiation losses being neglected. Knowing the temperatures, the individual efficiencies can also be determined. The pressure at the compressor suction flange was slightly below atmospheric, as local conditions necessitated the provision of a wooden duct for the air supply. An allowance of 2 per cent. was made to cover bearing friction, gland leakage, and heat loss by radiation. Owing to a source of error in the measuring arrangements for the test, the loss of head in the exhaust duct had to be estimated analytically. This loss of head, with a length of duct of about 15 m. of 1,800 mm. diameter, 9 m. of 2,200 mm. diameter, 15 m. difference of level and three bends, provided with deflecting vanes, amounted—as was calculated after deduction of

TABLE I.—*Test Results.*

| | Test No. I. Light. | Test No. II. About 4,000 kW. | Test No. III. About 3,000 kW. |
|---|---|---|---|
| Date of test | 7.7.39 | 7.7.39 | 7.7.39 |
| Duration of test .. .. min. | 15 | 60 | 30 |
| Kind of fuel used | | gas oil | |
| Moisture content .. per cent. | | 0·0 | |
| Ash content .. „ | | 0·0 | |
| Elementary analysis C „ | | 84·07 | |
| H „ | | 12·05 | |
| S „ | | 0·64 | |
| Net calorific value B.Th.U. per lb. | | 18,257 | |
| Gross calorific value „ | | 19,522 | |
| Density at 68 deg. F. .. .. | | 0·851 | |
| „ 77 „ .. .. | | 0·848 | |
| „ 86 „ .. .. | | 0·845 | |
| Fuel consumption of gas turbine lb. per hour | 1,812 | 4,338 | 3,649 |

TABLE II.—*Electrical Readings.*

| | Test No. II. From 10·10 to 11·10. | Test No. III. From 11·25 to 11·55. |
|---|---|---|
| Exciter current .. amperes | 130·8 | 108·4 |
| „ voltage .. .. volts | 102·7 | 84·9 |
| „ power .. .. kW | 13·4 | 9·2 |
| Generator voltage: Phase T-S volts | 6,611 | 6,724 |
| „ R-S „ | 6,580 | 6,716 |
| „ R-T „ | 6,616 | 6,691 |
| Average „ | 6,602 | 6,710 |
| Generator current: Phase R amperes | 363 | 270 |
| „ S „ | 343 | 256 |
| „ T „ | 349 | 261 |
| Average „ | 352 | 262 |
| Power factor .. .. .. .. | 0·998 | 0·999 |
| Output from wattmeter readings kW | 4,015 | 3,041 |
| kWh | 4,015 | 1,521 |
| Output from watt-hour meter readings kW | 4,021 | 3,057 |
| kWh | 4,021 | 1,529 |

# TESTS OF 4,000-KW. GAS-TURBINE SET.

*Fig.5.*

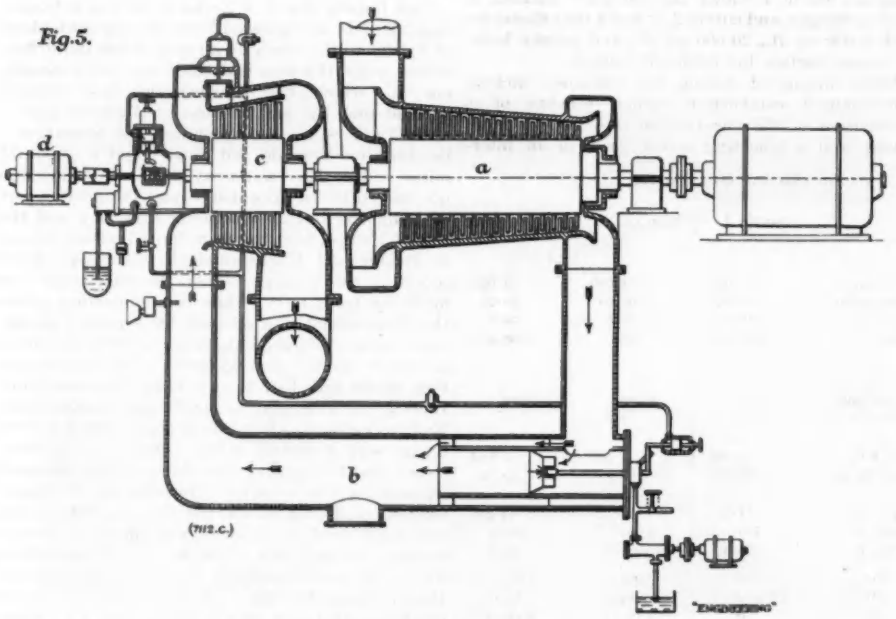



*Fig.6.*

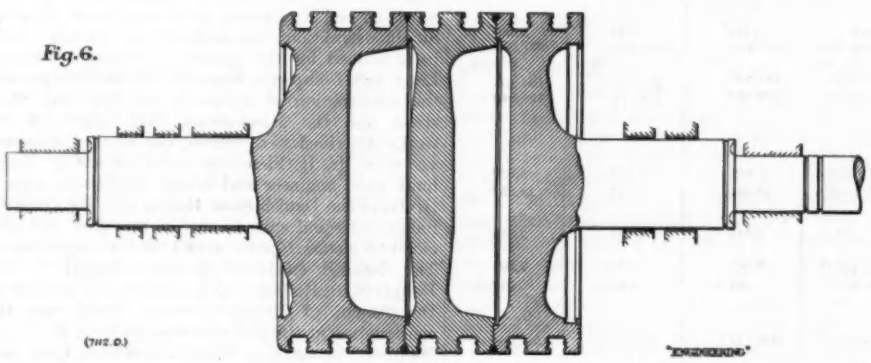



*Fig.7.*

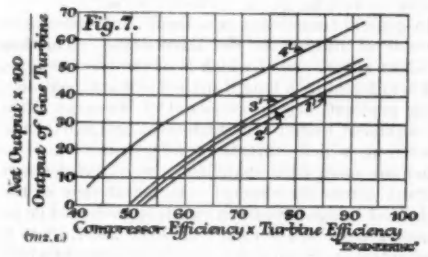



*Fig.8.*

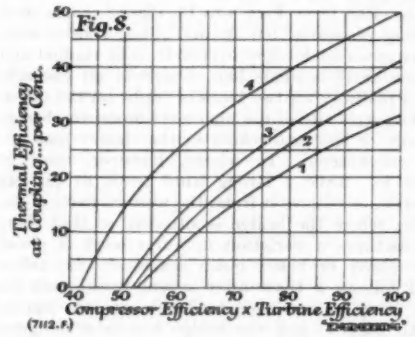
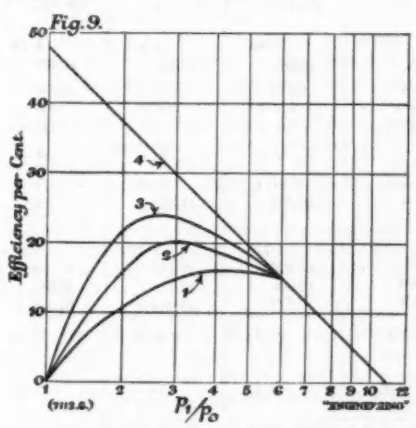



*Fig.9.*




the natural draught—to 1·102 in. w.g. This value was calculated as accurately as possible, because the conditions on site will be approximately the same as those obtaining during the test, so that no correction of the guarantees is necessary in this respect.

*Governing Tests.*—During load changes the amount of fuel is regulated directly by the governor, which allows of variations over a range of no-load to full-load and vice versa. The speed variation during these trials was read directly on the tachometer scale, the results being as follows :—

Unloading from full-load to no-load :

Momentary speed increase : 5·8 per cent. after 22·5 seconds.

Permanent speed increase : 2·5 per cent. after 1 minute 48 seconds.

Applying load from no-load to full-load :

Momentary speed drop : 5 per cent. after 33 seconds.

Permanent speed drop : 2·65 per cent. after 1 minute 45 seconds.

Perfect combustion was maintained throughout these tests, no smoke being visible at the stack outlet.

The efficiency of 17·38 per cent. could, of course, be further increased by the incorporation of an air preheater or of an exhaust-steam turbine. The builders, however, deliberately refrained from the employment of such means, in order to retain the extraordinary simplicity of the plant which, combined with the relatively high efficiency, will, in many practical cases, be the determining factor in favour of the installation of a gas turbine. In addition to the simple and reliable design of the components of the unit, compressor, combustion chamber, and turbine, there is the great advantage that no cooling water is required, making the location of the plant independent of any water supply. The low capital cost is also of importance, especially in regard to simplification of the foundations, small space requirements, and hence, reduction in constructional costs.

Dr. Adolf Meyer has rightly drawn attention* to the following applications where the gas turbine

TABLE III.—*Efficiency of Plant.*

| | Test No. II. | Test No. III. |
|---|---|---|
| Fuel consumption .. .. lb. per hour | 4,338 | 3,649 |
| Temperature at the gas-turbine inlet deg. F. | 1,025 | 916 |
| Net output at terminals .. .. kW | 4,021 | 3,057 |
| Net output at coupling .. .. ,, | 4,184·3 | 3,193·8 |
| Consumption per kWh at terminals lb. per kWh | 1·078 | 1·193 |
| Net calorific value of fuel B.Th.U. per lb. | 18,257 | 18,257 |
| Heat supplied by fuel per kWh at terminals B.Th.U. | 19,680 | 21,780 |
| Thermal efficiency referred to output at terminals .. .. .. per cent. | 17·38 | 15·67 |
| Efficiency referred to output at coupling ,, | 18·04 | 16·37 |
| Or, for the guaranteed conditions, namely : air temperature 68 deg. F. ; speed, 3,000 r.p.m., the figures are :— | | |
| Output at terminals .. .. .. kW | 4,000 | 3,026 |
| Output at coupling .. .. .. ,, | 4,163 | 3,162 |
| Temperature at gas-turbine inlet deg. F. | 998 | 890 |
| Thermal efficiency referred to terminal output .. .. .. per cent. | 17·38 | 15·67 |
| Thermal efficiency referred to coupling output .. .. .. per cent. | 18·04 | 16·37 |
| Fuel consumption, based on fuel having a net calorific value of 18,000 B.Th.U. per lb. .. .. .. .. lb. per kWh | 1·090 | 1·210 |
| Guaranteed consumption based on the net calorific value of 18,000 B.Th.U. per lb. lb. per kWh | 1·164 | 1·260 |

of the type described, or of slightly modified design, may be used with advantage :—

(1) Stand-by and peak-load sets, especially in the recently increasing number of cases where power plants are installed in bomb-proof locations for supplying key industries.

(2) Chemical plants and steelworks. Many gaseous reactions in the chemical industry are now effected under pressure, this resulting in substantial savings, especially if, as is generally the case, the products of the process consist of hot gases, which can be employed in a gas turbine to furnish power for driving the compressor. A number of installations of this type are already in operation in the United States and in Italy.

(3) A somewhat similar application of the gas turbine is for the purpose of supplying compressed air to blast-furnaces. The compressor is then made larger than is necessary for the air requirements of the turbine, and the excess power of the turbine, instead of producing electrical energy, is employed in furnishing the air requirements of the blast-furnaces. The pressures usually employed in blast-furnace practice are of the same order as those with which a normal gas-turbine plant operates, and, moreover, part of the necessary air preheating is effected by means of the turbine exhaust gases.

(4) The possibility of employing a gas turbine instead of steam or Diesel-electric drive for locomotives, in spite of the amount of development work required, is worthy of attention. The thermal efficiency of steam locomotives is only of the order of 8 per cent. to 12 per cent., and the superiority of the gas-turbine drive, with an overall efficiency of 15 per cent., including losses in the electrical transmission up to the driving wheels, is evident even compared with the performance of high-pressure condensing locomotives, especially as, by means of air preheating, the above efficiencies can be raised still further. The determining factors are the absence of any cooling-water requirements and, compared with the Diesel-electric locomotive,

* Paper delivered to the Institution of Mechanical Engineers, London, February, 1939. See ENGINEERING, vol. 147, page 247, (1939).

the small lubricating-oil consumption, the reduced wear, and the possibility of burning cheaper grades of fuel oil.

(5) Other applications, such as ship propulsion, are obvious.

Specially noteworthy are the possibilities of raising the efficiency. The diagrams, Figs. 7 and 8, page 3, show the thermal efficiency at the gas-turbine coupling for various efficiencies of the compressor and turbine, and for various temperatures at the turbine inlet, without heat recuperation from the exhaust gases. The thermal efficiency is defined as the ratio of the heat equivalent of the net coupling output to the heat supplied by the fuel. The curves 1′, 2′, 3′, and 4′, in Fig. 7, show the net output as a percentage of the gas-turbine power for temperatures, at the gas-turbine inlet, of 1,022, 1,200, 1,440, and 2,200 deg. F., respectively; and curves 1, 2, 3, and 4, in Fig. 8, show the thermal efficiencies with the same respective temperatures at the turbine inlet. The assumed compression ratios of the compressor $\frac{P_1}{P_2}$, were 4·2 with 1,022 deg. F., and 6·0, 7·2 and 12·0 with temperatures of 1,200, 1,440 and 2,200 deg. F., respectively, at the turbine inlet. The diagram, Fig. 9, shows the efficiency of a combustion turbine in terms of the surface area of the heat exchanger. The temperature of the gas at the turbine inlet is taken as 1,022 deg. F., and the ambient temperature at 68 deg. F. In this diagram, curve 1 shows the efficiency without a heat exchanger, and curves 2, 3, and 4 the efficiencies with 5,000 sq. ft., 20,000 sq. ft., and infinite heat-exchanger surface for 1,000 kW output.

Other means of raising the efficiency include fractionalised combustion, which consists of a subdivision of the gas turbine into two or more stages, and a reheating of the gases in an intermediate combustion chamber by means of additional injected fuel, coupled with intercooling of the air compressor. Improvement of the efficiency at fractional loads may be effected by dividing the turbine into two units, one driving the compressor, which may therefore run at the most favourable speed, and especially by raising the initial temperature, which will follow the improvement in heat-resisting qualities of constructional materials that may be expected to take place in the near future. When it is recalled that for every improvement of 1 per cent. in the efficiency of the turbine or of the compressor, due to improvements in the blade shape, the overall efficiency is raised by 4 per cent. or 3 per cent., respectively, it will be appreciated that the gas turbine has many promising possibilities which merit the attention of prime-mover designers and of leaders of industry.

TABLE IV.—PRESSURES, TEMPERATURES, AND AIR AND GAS QUANTITIES.

| | | | Test No. I. | Test No. II. | Test No. III. |
|---|---|---|---|---|---|
| *Air Compressor—* | | | | | |
| Abs. pressure at compressor inlet | $p_{1c}$ | lb. per sq. in. | 14·056 | 14·056 | 14·056 |
| " " " " outlet | $p_{2c}$ | lb. per sq. in. | 53·72 | 61·69 | 60·26 |
| Temperature at compressor inlet | $t_{1c}$ | deg. F. | 73·8 | 77·6 | 78·8 |
| " " " outlet | $t_{2c}$ | deg. F. | 357·8 | 397·2 | 393·4 |
| *Combustion Chamber—* | | | | | |
| Fuel quantity (calorific value = 18,257 B.Th.U. per lb.) | $G_F$ | lb. per hour | 1,812 | 4,338 | 3,649 |
| Fuel temperature | $t_F$ | deg. F. | 75·2 | 75·2 | 77 |
| *Gas Turbine—* | | | | | |
| Pressure drop in stack (calculated) | $\Delta P_{Stk}$ | in. WG. | 0·866 | 1·102 | 1·024 |
| Abs. pressure at turbine inlet | $p_{1t}$ | lb. per sq. in. | 52·80 | 60·77 | 59·31 |
| " " " " outlet (barometric press. + $\Delta P_{Stk}$) | $p_{2t}$ | lb. per sq. in. | 14·21 | 14·22 | 14·215 |
| Temperature at gas-turbine inlet | $t_{1t}$ | deg. F. | 705·2 | 1,067 | 987·8 |
| " " " outlet | $t_{2t}$ | deg. F. | 325·4 | 532·4 | 487·4 |
| *Generator—* | | | | | |
| Terminal output | $L_{term}$ | kW | 0 | 4,021 | 3,067 |
| Generator losses | $L_L$ | kW | 0 | 161·3 | 136·8 |
| Coupling output | $L_{cGen}$ | kW | 0 | 4,184·3 | 3,193·8 |
| *Air Volume Delivered by Compressor—* | | | | | |
| Speed | $n$ | r.p.m. | 3,020 | 3,020 | 3,030 |
| Air volume (from speed-volume curve) | $V$ | cub. ft. per hour | 6,992,330 | 6,992,330 | 7,027,650 |
| Air density at inlet ($\gamma_1 = p_{1c}/R\,T_{1c}$) | $\gamma_1$ | lb. per cub. ft. | 0·0710 | 0·0706 | 0·0704 |
| Weight of air $G_A = \gamma_1 V$ | $G_A$ | lb. per hour | 497,808 | 493,838 | 494,400 |
| Weight of gases $G_G = G_A + G_F$ | $G_G$ | lb. per hour | 499,620 | 498,176 | 498,049 |
| *Temperature at Gas-Turbine Inlet, Calculated from Fuel Quantity—* | | | | | |
| Heat supplied with air per mol.* at temperature $t_{2c}$ (from physical tables) | $H_1$ | B.Th.U. per mol. | 5,688 | 5,940 | 5,920 |
| Net calorific value of fuel | $H_u$ | B.Th.U. per lb. | 18,257 | 18,257 | 18,257 |
| Heat supplied by fuel per mol. of furnace gases $H_2 = \frac{G_F \cdot H_u}{G_G} \cdot m \quad (m = 29·0)$ | $H_2$ | B.Th.U. per lb. | 1,921 | 4,608 | 3,883 |
| Total heat supplied $H_1 + H_2$ | $H_{tot}$ | B.Th.U. per lb. | 7,609 | 10,548 | 9,803 |
| Temperature at turbine inlet | $t_{1T}$ | deg. F. | 627·5 | 1,025·5 | 917·5 |
| *Gas Quantity from Flow Formula—* $G_G = C \frac{p_{1t}}{\sqrt{T_{1t}}} \sqrt{1 - \left(\frac{p_{2t}}{p_{1t}}\right)^2}$ | $G_G$ | lb. per hour | 498,248 | 495,602 | 501,996 |
| Air quantity $G_G - G_F$ | $G_A$ | lb. per hour | 496,436 | 491,264 | 498,347 |
| *Compressor Power—* | | | | | |
| Compression ratio | $p_{1c}/p_{2c}$ | | 3·82 | 4·38 | 4·28 |
| Adiabatic drop | $H_{ad}$ | ft. | 46,260 | 52,403 | 51,673 |
| " power | $L_{ad}$ | kW | 8,650 | 9,710 | 9,660 |
| " temperature rise | $\Delta t_{ad}$ | deg. F. | 277·7 | 309·2 | 305·6 |
| Measured " " | $\Delta t_m$ | deg. F. | 316·4 | 352 | 347·6 |
| Efficiency from temperatures $\eta_{ad_t} = \frac{\Delta t_{ad}}{\Delta t_m}$ | $\eta_{ad_t}$ | | 86·4 | 86·6 | 86·9 |
| Coupling efficiency $\eta_{ad_c} = \eta_{ad_t} - 2$ per cent. | $\eta_{ad_c}$ | per cent. | 84·4 | 84·6 | 84·9 |
| Power at coupling | $L_{cc}$ | kW | 10,250 | 11,480 | 11,380 |
| *Gas-Turbine Power—* | | | | | |
| Expansion ratio | $p_{1c}/p_{2c}$ | | 3·715 | 4·27 | 4·17 |
| Adiabatic drop | $H_{ad}$ | ft. | 63,976 | 95,208 | 87,206 |
| " power | $L_{ad}$ | kW | 12,000 | 17,725 | 16,460 |
| Coupling power $L_{cT} = L_{cc} + L_{cGen}$ | $L_{cT}$ | kW | 10,250 | 15,664·3 | 14,573·8 |
| Efficiency from power ratio $\frac{L_{cT}}{L_{ad}}$ | $\eta_{ad_T}$ | per cent. | 85·4 | 88·4 | 88·4 |
| *Total Efficiency of Compressor and Turbine—* $\eta_{tot} = \eta_{ad_C} \cdot \eta_{ad_T}$ | $\eta_{tot}$ | per cent. | 72·1 | 74·8 | 75·0 |

* The mol is here taken as a weight numerically equal to the equivalent molecular weight $m$ in lb. of the gas mixture.

## THE STORSTROM AND MASNEDSUND BRIDGES, DENMARK.

THE Danish island of Zeeland, on which Copenhagen stands, is separated from the adjacent island of Falster to the south by an arm of the Baltic Sea. At one point this arm is divided into two channels, one of which—the Masnedsund—lies between Zeeland and the small island of Masnedo and is about ¼ mile wide, while the other—the Storstrom—lies between Masnedo and Falster and is about 2½ miles wide. This waterway forms a connection not only between Copenhagen and the greater part of Denmark, but also between that city and the rest of Europe, over the train ferry between Gedser in Falster and Warnemünde in Germany. Until recently, the passage across the Storstrom was made by train ferry, while communication across the Masnedsund was effected by a narrow single-track railway bridge. The inconvenience and delay caused by the use of train ferries on such an important traffic link had been evident for some time. Indeed, as long ago as 1887 the Danish State Railway authorities worked out a plan for a low-level bridge with a central swing span across the Storstrom, and the scheme was subsequently discussed on more than one occasion. In 1914, the alternative suggestion of a tunnel was put forward, but nothing was done until, in more recent times, it became evident that provision would have to be made both for rail and road transport. In 1931, therefore, the Danish State Railways prepared a scheme for a combined road and railway bridge and soon afterwards placed a contract with the Dansk Engelsk Staalkonstruktion Aktieselskab—a Danish company formed for the purpose by Messrs. Dorman, Long and Company, Limited, Middlesbrough—for the construction of bridges across both the Storstrom and the Masnedsund. The whole of the works described were carried out under the supervision of Mr. H. Flensborg and Professor A. Engelund, chief engineer and bridge consultant, respectively, of the Danish State Railways. The concrete foundations and substructure were sublet and executed by Messrs. Christiani and Nielsen, Copenhagen. The detailed steelwork designs adopted by the Danish State Railways were prepared by the Bridge Department of Messrs. Dorman, Long, and the construction at the site was supervised by Mr. G. A. Maunsell, as agent of Messrs. Dorman, Long and managing director of the Danish company.

In general terms, this new traffic link consists of a low-level bridge over the Masnedsund. This has six short spans, one of which is of the bascule type, and is followed by a long S-shaped embankment on a rising gradient, across the island of Masnedo. This embankment leads to the high-level bridge over the Storstrom, which consists of fifty spans, three of which are navigation spans and are situated about midway across the channel. An aerial view of the high-level bridge appears in Fig. 1, opposite, while its general lay-out will be clear from Figs. 2 to 7, Plate 1. The central navigation span, the construction of which will be clear from Figs. 8 to 11, Plate 1, has a clear opening of nearly 400 ft. and gives a headroom, above mean sea level, of over 85 ft. The viaduct and bridges carry a single line of railway on one side and a roadway for two lanes of traffic on the other.

The actual site of the high-level Storstrom bridge is more or less landlocked, so that heavy seas are not encountered. In winter, however, there is much ice, while a strong wind tends to pile up water in, or remove it from, the western parts of the Baltic, where the bridge is situated, so that there is sometimes a variation in water level of about 3 ft. above or below mean sea level. If such a wind follows a thaw after severe frost, pack ice may be piled as high as 15 ft. on the shores of the islands, and the bridge has been designed to resist the impact of this. The land bordering the site of the bridge is rather flat and the greatest sea depth is about 46 ft. The sea bottom consists, generally, of a layer of light grey-coloured glacial clay, which is rich in lime and from 13 ft. to 33 ft. thick. This clay, which overlies chalk, was found to be rather soft in places and sometimes stiffer on top than below. It was generally fairly watertight, but in some parts it contained a good deal of sand and was liable to blow out under hydrostatic pressure from beneath. For this reason,

# THE STORSTROM BRIDGE, DENMARK.

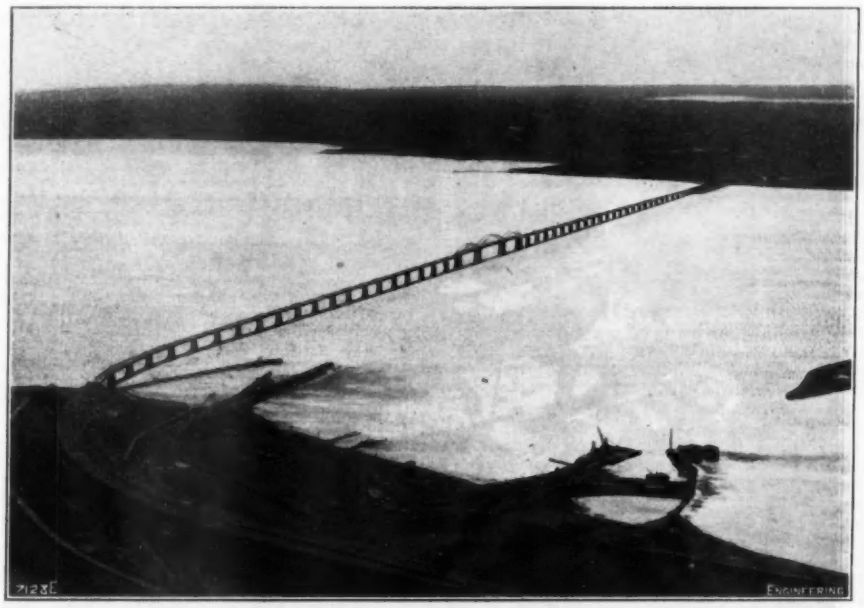



FIG. 1. AERIAL VIEW OF BRIDGE FROM MASNEDO.

some of the foundations could not be pumped out and the excavation work and the deposition of the concrete foundation slabs had to be carried out under water. In most cases, however, the foundations of the piers were safely carried out in the dry.

The total length of the bridge is 10,535 ft., which is made up of 21 approach spans on the Masnedo side, 26 approach spans on the Falster side, and three navigation spans in the centre. Ten of the approach spans on the Masnedo side are 204 ft. 2 in. long, ten 189 ft. 7 in. long, and one 187 ft. 7 in. long. On the Falster side, twelve of the spans are 204 ft. 2 in. long, twelve 189 ft. 7 in. long, one 188 ft. long, and one 175 ft. long. The two side navigation spans are 335 ft. 8 in. long, and that in the centre 447 ft. 5 in. long. There is a clear head room under the navigation spans of 85 ft. 4 in. The four piers which support the navigation spans are 118 ft. high and weigh 8,000 tons, while the other 45 are of varying heights and sizes, the tallest being 125 ft. 4 in. high. In general, the larger piers consist of an oval mass-concrete foundation slab situated below the sea bottom. This slab was designed to spread the weight over a fairly large area of clay on which the bearing pressure was limited to about 3·2 tons per square foot. On this slab rests a mass-concrete prism, which supports a solid reinforced-concrete shaft. This shaft is faced with granite and extends from 8 ft. 3 in. below to 8 ft. 3 in. above water level. It is surmounted by a second slender cellular reinforced-concrete shaft. The reinforcing steel was intended mainly to counteract cracking due to shrinkage of the concrete. The method of construction, and all special plant employed on the foundations, were evolved by Messrs. Christiani and Nielsen.

The foundations of the piers supporting the navigation spans were excavated within a steel sheet pile cofferdam, inside which the concreting was subsequently carried out. For this purpose, a timber platform and surrounding waling, supported on timber piles, were first set up just above water level. On this structure, the timber piles supporting which were driven by floating plant in open water, was mounted a pile-driving plant of the drop-hammer type. This travelled on rails round the periphery of the platform, but before any steel piles were driven a heavy built-up steel girder waling was put together on the surface, then suspended from the timber staging, and finally lowered through the water to a point about 18 ft. below water level. The waling was oval in shape to correspond with the shape of the foundation Guided by the timber waling above and the steel waling below water level, the outer ring of steel sheet piles was then hammered down, adjacent piles being spot-welded along the interlock and driven together in pairs to save time. After the cofferdam had been pumped out, a heavy reinforced concrete waling was cast *in situ* at the bottom. The whole hydrostatic head due to 35 ft. of water plus 10 ft. of external clay was, therefore, eventually borne by the three walings—one timber, one steel, and one concrete. The piles were of the Dorman Long-Krupp K. 111 type and were rolled in England out of Chromador steel. Considered as vertical beams, they were stressed up to about 10 tons per square inch.

After the concrete waling had set, the excavation was carried out by hand and by grab to a depth of about 10 ft. below the sea bed. The concrete foundation slab was then deposited by means of a low-level floating concreting outfit. The lower concrete waling was incorporated as part of the foundation slab. When the pier shaft had been built up above sea level, the steel piles were cut off at about the level of the sea bottom. This operation was carried out by divers working from the outside, under-water gas burners being used for the purpose. In the case of some of the steel pile cofferdams, the bottom was not sufficiently firm and impervious to permit of pumping out, and in these cases both excavation and concreting had to be effected under water.

The remaining piers to the number of 41 were dealt with by means of floating steel cofferdams, which were called "units." These units were of two kinds: internal, in which the steel pile foundation ring was driven outside the shell, and external, in which the piles were driven inside the shell. Views of an external unit are given in Fig. 12, page 6, and Fig. 14, page 12. The external units were designed for use where the bottom was bad or doubtful. Two internal units were used to construct 27 pier foundations where the ground was sufficiently good to permit work to proceed in the dry, while two external units were employed to construct 14 pier foundations where the dewatering of the unit was considered inadvisable. The units were, as will be seen, oval in plan and had two steel skins with air compartments between them. They served as working platforms for operating plant, as guides for driving the ring of foundation piles, and as cofferdams. In addition, those of the internal type acted as strutting for the under-water portion of the concrete pier shafts. Before being floated out a few timber piles were driven down in a ring with their tops levelled at about the level of the sea bottom. The bottom plate of the unit came to rest upon these piles after it had been floated into position and sunk. In some cases the steel sheet piles forming the oval ring which enclosed the foundation slab were interlocked and hung round the unit in harbour. In others, the piles were pitched after the unit had been placed. The piles were driven by a McKiernan-Terry hammer until the tops were level with the bottom strake of the unit, compressed air instead of steam being used for this purpose, as much of the work was under water. When the piles had been driven they made nearly continuous contact with the steel waling through their hardwood block fillers. The narrow space between the piles and the waling was then made watertight by plugging it with rope impregnated in tallow. The subsequent pumping out of the water within the unit caused this rope to be sucked in tightly, and to seal the cofferdam. In the case of the external units, there was a V-shaped space between the tops of the piles and the inside sloping shell of the unit, which was sealed with concrete.

After the internal unit had been pumped out excavation proceeded by hand and grab, and the concrete foundation slab was deposited in the dry. In the case of the external units, pumping was not resorted to until the excavation had been completed and the concrete foundation slab had been deposited under water. The building up of the lower part of the pier shaft was then carried out, the interior sloping skin of the internal unit itself acting as the form against which to run the concrete. The concrete having been finished off and carefully levelled at 8 ft. 3 in. below water, the unit was floated off. Vertical tubes had been built at intervals between the two skins of the unit through which posts could be inserted. When these rested on the base concrete, they could be jacked down and so provide the necessary uplift to break the bond between the concrete and the internal face of the unit. In most cases the units lifted quite easily, when the water inside the compartments had been pumped out, but the jacking posts were a reasonable precautionary measure. Since the units, when fully pumped out, drew more than 8 ft. 3 in. of water, they could not be floated over the concrete piers on a level keel. It was, therefore, necessary to water-ballast them on one side and to careen them over the piers.

The under-water concreting was carried out by running fairly plastic concrete down a 10-in. tremie pipe. In this way, fresh concrete was fed in at or near the bottom of the mass and did not, therefore, come in contact with the water. To begin with, the tremie pipe was lowered into the compartment to be concreted with a flat steel plate at its bottom end. Concrete was then fed into the tremie pipe through a hopper above water, the first batch of concrete being protected by a jute plug which it pushed down the tube in front of it. It was, of course, impossible to prevent the first few batches of concrete from being scoured or washed rather badly on emerging and spreading out sideways round the bottom of the tube. Afterwards, however, so long as the tube was carefully manipulated by raising and lowering to keep the flow of concrete proceeding steadily, it was possible to deposit the concrete with very little loss of cement.

In order that the concrete forming the foundation slabs might be brought to one compact plastic mass, the volume deposited at one time had to bear a certain relation to the output capacity of the mixing plant. The area was, therefore, subdivided into ten compartments by vertical shutters, which were lowered through the water and fixed in position by divers. Each compartment had a superficial area of about 40 sq. yd., and the depth of the concrete deposited being about 10 ft., the volume worked out at about 120 cub. yd. The tremie pipe was lowered in the centre of the compartment, so that the concrete had only 10 ft. at most in which to spread out laterally. The surface of the finished concrete sloped from the centre outwards at a gradient of about 1 in 10. Even on the top surface or the concrete there was very little laitance of washing out of the aggregate. Tests made by fixing sloping wooden drums in some of the compartments and afterwards inspecting the concrete which had been formed round these awkward obstacles showed that the quality of the work was satisfactory. The mix was 1 : 2½ : 2½

and, of course, the rather high percentage of sand and of water detracted from its strength. The concrete was, however, amply strong enough for all practical purposes, and was quite impervious. While concreting was in progress, a duplicate mixing outfit was provided, so that a breakdown should not cause a break in the continuity of operations.

Where the pier foundations were built inside interior units, the lower part of the pier shafts was formed by running the concrete up against the well-greased internal metal skin. The base of the shaft formed in this way resembled a prism bounded by a number of plane faces. The concrete was deposited in the dry from a ship fitted up for the purpose. The top of the prism was carefully levelled off and was surmounted by a diamond-shaped beading of asphalt mixed with sand. This beading was about 1½ in. wide by 1½ in. high and was intended to engage and form a water-tight joint with the bottom edge of the "middle body." The middle body of the pier shaft, a view of which is given in Fig. 16, on page 12, was, for the sake of lightness, constructed hollow with reinforced-concrete walls, which were faced with stones of Danish granite about 8 in. thick. These stones were laid in courses 8 in. deep. Erection was carried out on a slipway on shore, this procedure enabling a high standard of workmanship to be attained at a low cost. This operation took about a fortnight and, immediately on completion, the middle body was lowered down the slipway and straddled by a pair of specially-rigged barges. Its weight was then taken by a series of lifting screws suspended from overhead girders; and it was afterwards floated out between the barges and lowered upon its prepared seat so that its lower bearing edge rested on the asphalt bed mentioned above. A water-tight joint was thus automatically made with the concrete beneath. Two pins projecting below the middle body engaged with two funnel-shaped holes left in the base, so that exact registration of the two parts was obtained. Finally, the water was pumped out of the middle body, light reinforcing rods left in the base were bent up, and the interior was filled with concrete so that the middle body became monolithic with the base.

The upper part of the shafts projecting above water were shuttered with steel shutters raised in lifts of about 5 ft. at a time. The shutters stretched between a series of steel soldiers bolted to the concrete and were raised by means of chain blocks from a central steel gallows, which was, in itself, raised in stages as the work climbed upwards. The whole was specially designed for Messrs. Christiani and Nielsen, Limited, by Mr. C. Parry, of London. The concrete in the shafts was gauged, mixed, hoisted and deposited through chutes from a specially-equipped ship. Two such ships were used, one for low-level concrete work on the foundations and lower shafts and the other for high-level work. A view of the latter is given in Fig. 13, on page 12. To do the work in time, operations had to be organised so that each of the four units and each of the two concreting outfits, the middle body slipway, the floating pile-drivers and the shaft-shuttering and other plant were continuously in use without idle periods. At the same time, a steady sequence of completed piers had to be provided to absorb the output of the steel bridge-span construction yard. As there were a great many different types of piers and spans, the task of co-ordinating progress was a matter of complexity and had to be the subject of continuous forward planning and arranging as the work proceeded.

The approach spans of the Storstrom bridge, one of which is shown during erection in Fig. 15, on page 12, are constructed as deck-type plate girders of the cantilever type, with suspended spans 145 ft. 10 in. long in the alternate openings. These are supported on 29 ft. 2 in. cantilever arms. Each span is carried by two main plate girders, spaced 24 ft. from centre to centre and 12 ft. 0½ in. deep over the flange angles. The flanges consist of 12 in. by 12 in. angles, with from one to four flange plates, 27 in. wide. The web plates are ⅜ in. thick and are divided by a central longitudinal splice. The webs are stiffened by pairs of vertical angles on packings spaced from 35 in. to 87·5 in. apart. In addition, the compression side of the web plate is stiffened against buckling by short lengths of longitudinal angle midway between the flange and central splice near the centre of the anchor and suspended spans. High tensile steel rivets, 1 in. in diameter, in 1 1/16 in. holes were used throughout the main girders. The anchor spans are supported on fixed and expansion cast steel bearings, laid upon alternate piers. The fixed bearings are of the spherical rocker type, while the expansion bearings are of the single rocker Habercalt pattern with rockers 61⅛ in. high. The suspended spans are supported at both ends upon single cast-steel rockers, 32½ in. in diameter. These bear on flat steel seatings which rest on the projecting ends of adjacent spans. The fixed end of each suspended span is secured to the end of the cantilever arm by a vertical pin-joint midway between the girders in the plane of the girder top flange. The other end is allowed to expand by means of a knuckle working between jaws.

The girders are connected by full lateral systems in the planes of their top and bottom flanges, these systems being built up from pairs of starred angles. Provision is made in the top lateral system for resisting the tractive forces. Portal bracing is provided in the plane of the bearings of the anchor spans. The deck is carried by plated cross girders resting on top of the main girders and cantilevered out to support the roadway. The stringers are all of rolled joist sections. The railway stringers are framed into cross-girder webs and are connected by continuity plates. The roadway stringers rest on the top of the cross-girders and are connected to them by clips, so that limited longitudinal movement is possible. The rivets in the deck system are generally ⅞ in. in diameter. The deck is arranged to produce nearly equal moments on the two main girders. The railway track is carried on ballast in a reinforced concrete trough resting on the stringers. The roadway is carried on a reinforced concrete slab from the outer edge of which the footway slab is cantilevered without independent stringers. The deck slab is insulated with a bitumastic layer upon which rests a 4½-in. concrete wearing surface. The footpath is surfaced with 1-in. asphalt. A sliding joint is provided in all stringers at both ends of the suspended span and at the centre of the anchor span. The main roadway expansion joints are steel castings of the interlocking finger type. The footway and ballast trough expansion joists are of sliding plate construction.

*(To be continued.)*

## THE STORSTROM BRIDGE, DENMARK.

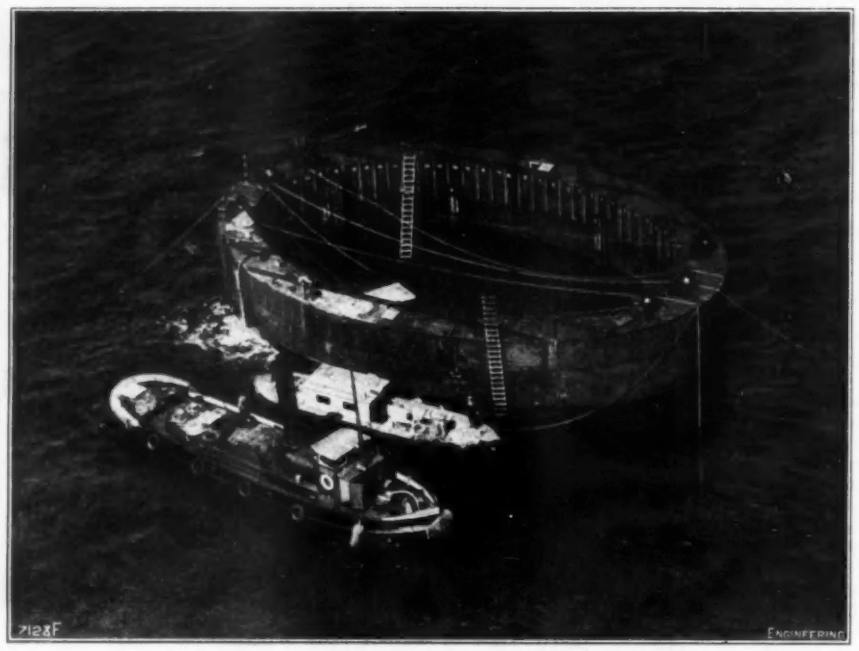



FIG. 12. EXTERNAL-TYPE UNIT FOR PIER CONSTRUCTION.

## TERMINAL VELOCITIES.*

By DR. HERBERT CHATLEY, M.Inst.C.E.

IN many engineering and physical problems the question arises as to the maximum velocity developed by a falling body in a fluid medium. To give an idea of the scope of this problem, two extreme examples can be adduced: the impact velocity of streamlined aerial bombs, and the speed with which the finest clay suspensions settle in water. Intermediate cases of interest are the landing speed of parachutes, the fall of rain or oil drops, the vertical-current speeds necessary in coal-dust or grain elevators, the suspension of sand and silt in rivers, the stability of clouds of vapour drops and the settlement of dust particles in a room. The Greek and mediæval philosophers taught that heavy things fall more quickly than light ones, until Galileo showed otherwise. Their statement was not entirely untrue; a light thing has a larger surface than a dense thing of the same weight, so that, on account of buoyancy and the resistance of the air, the heavy thing does fall faster in air and Galileo's law is only perfectly true in a vacuum, such as exists in the interplanetary spaces. It is also a question of size. The larger a thing is, the greater the velocity it can develop in air (or water), owing to the fact that its surface per pound is smaller. If it is sufficiently small it will not descend at all on account of the incessant bombardment of the molecules of the fluid, which keeps it perpetually balanced like a ball on a fountain.

When an elevated body is released it initially accelerates earthwards, according to the well-known gravitational law. As its velocity increases, the resistance of the air (or water) increases, and, after a certain time becomes equal to its weight. The velocity is then constant, and this is termed the "terminal velocity." For small bodies the period of acceleration may be very short indeed. A general view of this problem covers many matters. Thus, with minute bodies, we have the question of molecular bombardment, giving permanent suspension with the so-called Brownian motion. An example of this is Indian ink, which may be seen under a high-powered microscope to be in a state of agitation. A few drops of acid, or the introduction of some ordinary ink (which contains tannic acid) will cause the particles to coagulate and settle quickly. Indian ink is a case of what is termed colloid suspension, a colloid being simply a substance diffused into particles so small that their surface per unit weight is very large and various surface phenomena become conspicuous.

The diameters of the particles in which colloid phenomena are paramount range from 0·001 micron, or one ten-millionth of a centimetre (about the size of a large inorganic molecule) up to, say, 1 micron, or

* Paper prepared for delivery before the Junior Institution of Engineers in London. Abridged.

one ten-thousandth of a centimetre (a small cell or a large organic molecule). The terminal velocity for the smaller of these sizes is zero, and for the larger is still very small.

A sand particle 1 micron in diameter has a terminal velocity in water of about 0·001 mm. per second; in air, about 90 times as much. The velocity of sand in water increases with the square of the diameter until the latter is about 0·1 mm., or 100 microns. (Terminal velocity, about 9 mm. per second.)

The non-turbulent (Stokes') rules for spheres is as follows:—

$$\text{Velocity in centimetres per second} = \frac{218\,(s - w)\,r^2}{\mu},$$

where $s$ = specific gravity of the particle substance, $w$ = specific gravity of the fluid (1·0 for water, and 0·0012 for air at 20 deg. C.), $\mu$ = viscosity of the fluid (0·01 "poises" for water, at 20 deg. C. and 0·000181 for air, at 20 deg. C.), and $r$ = radius of particles in centimetres.

If $s = 2{\cdot}6$ and $d$ = diameter of particle in microns, $v = 0{\cdot}000872\,d^2$ in water, or $= 0{\cdot}0787\,d^2$ in air, in millimetres per second.*

Up to this stage the resistance to fall has been of the form known as laminar, viscous or non-turbulent surface drag, obeying Stokes' Law; but with larger particles the strains in the liquid outside a thin boundary layer become more than it can bear without spinning, and unless the object is of an ideal stream form and the fluid is perfectly quiet, a hydrodynamic or turbulent resistance, or "form drag," appears. This follows quite another rule, the terminal velocity varying as the square root of the diameter. Thus, a 2-cm. diameter silica sphere in water has a terminal velocity of nearly 1 m. per second. If the diameter is 2 m., the terminal velocity is about 10 m. per second and will take a few seconds to develop fully. A ship sinking in very deep water will attain a terminal velocity of the order of perhaps 30 m. per second long before reaching the bottom.

In air the conditions are slightly different. Buoyancy in air is negligible for solids, whereas for sand in water it reduces the effective weight some 40 per cent., and for lighter materials still more. The density and viscosity of air are much less than those of water (incidentally, the ratio of viscosity to density is about fourteen times as great in air as in water); the viscosity of air rises with temperature, while that of water falls; and further, at the velocity of sound in air, about 350 m. (1,140 ft.) per second, the coefficient of resistance is suddenly increased (say, 100 per cent.) and all streamlining of the leeward side of the object becomes ineffective. The terminal velocities of sand particles falling in air are about ninety times those in water in the non-turbulent state, but the ratio is smaller in the turbulent state.

The terminal velocities in turbulent flow, depending on "form drag," are more difficult to determine exactly than those fixed by non-turbulent conditions. Even if the shape is a perfect sphere and the fluid free from currents, the coefficient is a normal minimum when the Reynolds number is about 4,000.

The rule for turbulent resistance for spheres (diameter $d$ cm.) is:

$v$ = velocity (cm. per second).

$$= 36\sqrt{\frac{(s - w)\,d}{w\quad C_D}}$$

$C_D$, the absolute coefficient of drag,

$= 24{\cdot}00$ when $v\,d\,\frac{w}{\mu} = 1$ (non-turbulent);
$4{\cdot}00$ " $= 10$;
$1{\cdot}00$ " $= 100$;
$0{\cdot}40$ " $= 4{,}000$ (normal minimum)
$0{\cdot}50$ " $= 20{,}000$-$30{,}000$;

and drops abruptly to

$0{\cdot}10$ when $v\,d\,\frac{w}{\mu} = 40{,}000$.

For sand (where $d$ is in microns),

$v$, in mm. per second $= 4{\cdot}55\sqrt{\frac{d}{C_D}}$ in water

or

$$168\sqrt{\frac{d}{C_D}} \text{ in air.}$$

If the particle is not spherical the conditions become very complex. The body tends to set itself athwart the direction of descent owing to the eccentricity of the centre of pressure, and if the form is flat a lateral glide is developed and the flake oscillates from side to side. The silhouette which gives the greatest area is that which determines the terminal velocity, so that a scale-like particle may have a terminal velocity much smaller than that of a sphere of the same mass. A sphere, moreover, is not the form which has the smallest fluid resistance, between the laminar state and the speed of sound. The fish-shaped form, with a bluffly-rounded nose and drawn-out tail, has a very little form drag, its resistance being almost entirely skin friction. This form, therefore, is used for aerial bombs, with a tail fin to maintain directional stability. The resistance of such a form may be only about one-sixth that of a sphere of same diameter, so that it tends to develop a terminal velocity $\sqrt{6}$ times as great as a sphere of the same diameter and the same weight. If the fish shape has the same volume and weight as the sphere, the terminal velocity is still further increased to perhaps four times that of the sphere. In the discussion on the author's paper to the Society of Engineers ("Engineering Aspects of Air-Raid Protection," November 7, 1938), it was mentioned that the terminal velocity of a parachutist (before his parachute was opened) was under 200 ft. per second, whereas speeds of nearly 1,000 ft. per second can occur with bombs; but there is no inconsistency in this, as the man and parachute are by no means streamlined, and the height from which the fall takes place is very rarely so great as can be the case with an aerial bomb.

Such velocities can only be developed from a great height. The free vacuum velocity is approximately $8\sqrt{h}$ ft. per second, so that even in a vacuum the landing velocity is only 800 ft. per second from a height of 10,000 ft., and in air appreciably less. Terminal velocities above 1,100 ft. per second (about the velocity of sound) are practically impossible, owing to the enormous initial height required and the fact that streamlining ceases to be effective at this velocity. Incidentally, this velocity, say, 800 m.p.h., appears to be the ultimate limit for the speed of aerial flight. By a coincidence, this is nearly equal to the earth's surface speed of rotation, so that an aeroplane cannot hope to move faster than the sun's apparent motion.

One of the most useful applications of the terminal velocity is in the computation of the power required to sustain bodies. Since a weight W, falling in a fluid with a terminal velocity $V_t$, loses potential energy $c\,W\,V_t$ per second ($c$ is a buoyancy correction), this same energy per second is required to keep it at a constant level. Two simple examples of this are: (1) An aeroplane (weight W, buoyancy negligible), the vertical component of free gliding velocity of which is, say one-eighth the regular flying speed V, requires an energy of $\frac{W\,V}{8}$ per second merely to sustain it, apart from that required to drive it through the air against the horizontal resistance.

Thus, if the weight is 2,200 lb. and the flying speed is 160 ft. per second, a power of $\frac{2{,}200 \times 160}{8 \times 550} = 80$ h.p. is required, merely to sustain it. (2) If a river contains $1\frac{1}{2}$ lb. of sediment per cubic foot of water, and the representative terminal velocity of the particles is 0·001 ft. per second, for every cubic foot,

$$1\tfrac{1}{2} \times \frac{1{\cdot}6}{2{\cdot}6} \times \frac{1}{1{,}000} = 0{\cdot}001 \text{ ft.-lb. per second}$$

is required to sustain the particles. (The term $\frac{1{\cdot}6}{2{\cdot}6}$ is the buoyancy factor.)

In travelling for one second along the river, this cubic foot falls $i\,v$ ft. where $i$ is the hydraulic gradient and $v$ the effective mean stream velocity; and it loses $63{\cdot}5 \times i\,v$ ft.-lb. of potential energy in one second, 63·5 being the weight of the silty water in pounds per cubic foot. Then $i\,v$ must equal at least $\frac{1}{63{,}500}$ if the turbulence is to keep the particles supported. Thus, if $v$ is 3 ft. per second, the gradient must exceed 1 in 190,500. The bed friction generates turbulence and kinetic energy, and energy is required to overcome bed friction, so that the value of $i$ may actually be greater.

If we substitute $v_t$ for 0·001 and $\frac{8w_1}{13}$ for the net buoyant weight of silt per cubic foot, $w_1$ being the gross weight of silt per cubic foot, we get—

$$i\,v = \frac{8}{13} \times \frac{w_1\,v_t}{62{\cdot}5 + \frac{8w_1}{13}},$$

showing that the gradient necessary increases as $w_1$ and $\frac{v_t}{v}$. This expression may be turned round to find the maximum silt content from the slope. For the transportation of grain, coal, etc., this sustentation energy has to be combined with the energy required to lift the suspended material up the vertical parts of the pipe or round bends. In a vertical pipe the fluid ascends more quickly than the suspended material, the difference being the terminal velocity.

There is a close association between the terminal velocity and the so-called critical velocity of suspension, which is the mean velocity in a horizontal pipe at which the turbulent components are sufficient to keep the material in suspension. It is at least six or seven times as great as the terminal velocity, depending also on the roughness of the pipe walls. The transportation of slack coal is daily becoming of more importance, and a few figures as to the energy required to carry it pneumatically will, perhaps, be of interest.

If the standard particle is, say 0·1 in. cube, and the density 1·3, the terminal velocity may be found approximately from the rule given for sand spheres in air:—

$$V = 168\sqrt{\frac{d}{C_D}}$$

0·1 in. = 2·5 mm., or 2,500 microns; so that

$$V = \frac{168 \times 50}{\sqrt{C_D}}.$$

At medium velocities $C_D$ is about 0·5 or more. V is then less than 12,000 mm. per second, or 1,200 cm. per second, or about 48 ft. per second. The cubic shape and lower density make a reduction to, say, 30 ft. per second. The air velocity in the pipes must then be of the order of $7 \times 30$ = say, 200 ft. per second. If there are 10 lb. of coal in every cubic foot of air mixture, the quantity of air required is nearly 224 cub. ft. per ton transported. The energy required to sustain the coal in the air is $\frac{2{,}240 \times 30}{550} = 120$ h.p. for each ton kept in suspension in the whole pipe system. To this must be added the power required to lift the tonnage to the desired height, and also that necessary to keep the air moving through the system at the stated velocity of 200 ft. per second, which can be found from ventilating tables. Obviously, the smaller the volume in the pipe system the better, but the sizes of the pipes are determined chiefly by the air quantities involved. Thus, if 100 tons per hour is to be transported at the above rate, 22,400 cub. ft. per hour of air is required. In the elevation of grain from a hopper or ship's hold to a level somewhat above the receiver out of which it flows to a second container (say, 50 ft. lift), modern plants consume about 0·8 horse power hour per ton. Considered just as a lift, this is only about 7 per cent. efficiency, but there is also the sustentation energy to be considered. The terminal velocity of wheat grains is about the same as that of the slack coal referred to above. Lightness is offset by a better shape, so that the energy required to sustain it is about the same.

A rather curious case of terminal velocity occurs in connection with the fall of meteorites. These bodies arrive at the upper atmosphere with a velocity relative to the earth of ten or more miles per second. (The earth's velocity relative to the sun is about 20 miles per second. The free velocity of gravitational fall to the earth in a vacuum from infinite distance is 7 miles per second.) The terminal velocity of such a body depends on the size and density of the meteorite. Under the earth's gravity in air it would develop a velocity probably less than 1 mile per second, and in this case the meteorite's velocity tends to be reduced towards this value by the air resistance. If the entrance velocity is 10 miles per second, the kinetic energy per pound is $\frac{(10 \times 5{,}280)^2}{64}$ = about 44,000,000 ft.-lb. If converted into heat by friction, this would raise 1 lb. of water 50,000 deg. F. It is easy to see that the meteorite will probably be largely vaporised and that the particles which survive may arrive at the earth's surface with more than the normal terminal velocity.

The size of drops depends on their initial formation, the vapour tension of the fluid and the surface tension. The latter is much affected by electrostatic conditions, so that raindrops vary considerably. By the formula given for turbulent motion in air, assuming $C_D$ as unity and the diameter of the drop as 100 microns, the velocity is about 1 m. per second, or ten times as much if the drop is 1 cm. diameter. Observations will show that the latter size is quite unprecedented. The large drops of a thunderstorm make spots perhaps 2 cm. diameter, but if the thickness of the spot is 10 microns, the diameter of the drop was only about 2 mm. Scotch mist falling at, say, 10 mm. per second (non-turbulent flow), may have drops with a diameter of 20 microns (0·002 cm.).

---

* See "Measurement of the Fineness of Powdered Materials," by Dr. H. Heywood, *Proc. Inst. Mech. E.*, vol. 140, page 257 (1938).

---

STAINLESS-STEEL RAILWAY PASSENGER COACHES.—It is stated in a recent number of *The Nickel Bulletin*, which is issued by Messrs. The Mond Nickel Company, Limited, Thames House, Millbank, London, S.W.1, that the Pennsylvania Railroad has recently placed in service twelve 85-ft. stainless-steel passenger coaches. These are in addition to two similar coaches delivered earlier in 1939. The coaches were built by Messrs. Budd Manufacturing Company.

## SIX-SPINDLE AUTOMATIC CHUCKING LATHE.

THE account here given of the six-spindle automatic chucking lathe shown in the accompanying illustrations, Figs. 1 and 2, is intended rather to indicate the scale on which this type of machine is now manufactured than to describe it in detail. The lathe, known as the Acme-Gridley 12 in. R.P.A. 6-spindle chucking machine, is the latest design of Messrs. The National Acme Company, 170, East 131st-street, Cleveland, Ohio, U.S.A., the dimension 12 in. indicating the diameter of the chucks and, therefore, also the maximum diameter of work that can be dealt with, assuming that the parts have an unmachined projecting part that can be gripped in the chuck jaws. The general construction of the machine is indicated in Fig. 1. The column on the right houses the gearbox for both the spindle-speed changes and the tool-slide feed changes, the drive being by flat belt from a 40-h.p. motor mounted on the column. The hexagonal tool slide, with its traversing shaft and sliding bracket, is seen in the centre and below it is the drive shaft from the gearbox to the chuck spindles, etc. The chucks are hydraulically-operated as regards the opening and closing of the jaws They are visible on the left of Fig. 1, with the side tool slides above and below them, but are more clearly shown in Fig. 2, where an actual work and tool set-up is shown. The chucks are, of course, indexed round six positions to suit six tools, if the operations concerned call for so many.

The machine is intended for mass-production work, the particular work shown in Fig. 2 being a tough-alloy casting of 18 lb. which is machined in 52 seconds from the rough casting seen upright on the side tool slide in the foreground to the finished part lying on its side near it. It is stated that this machining time is only one-fifth of that required for the same amount of machining expended in the methods previously in use. The tools employed call for some comment. The heads are bolted to the tool slide and all make the same traverse simultaneously, but the upper tool has, apparently, an independent traverse, as the spindle to the left would seem to indicate. This is, however, not the case, the spindle being for rotating the cutters. This rotation, which is derived from a unit situated in the gearbox housing and driven by gears from the shaft which drives the work spindles, is in the opposite direction to the rotation of the work spindles, with the result that a high lineal speed is obtained. A similar device may be used for high-speed drilling. The tool is finishing the major internal bore in the illustration, the work concerned being in the top chuck of the three in the foreground. This is mentioned as, owing to the angle from which the photograph reproduced was taken, the tool looks as if it were entering the part in the top chuck to the rear, which is not the case. The tool immediately below the rotating one is fixed and is engaged on rough-cutting the minor bore of the casting. The lowest tool, also fixed, gives a finishing cut to this bore. The tool in the lower background turns the outside diameter.

The tool slide is in the retracted position in Fig. 2, and both it and the side tool slides are traversed by cams in the gearbox housing. The maximum turning length is 12 in., and the feed range is capable of variation within very wide limits by fitting different cams. The range when using a specific cam is, moreover, wide, different rates being obtained by pick-off gears. These gears are situated in the gearbox housing, and are readily accessible through convenient doors. The spindle-speed changes are also effected by pick-off gears. The two sets of gears are interchangeable, an arrangement which reduces the number of change gears to be stocked to suit the speed and feed changes required. The design provides for the fitting of 28 change gears, but, obviously, this complete range gives finer changes than are likely to be required by any user. The standard set supplied with the machine consists, therefore, of eight gears, which give four changes to the speeds and five changes to the feeds. The drives are provided, however, with a sliding gear, which doubles the number of changes and gives fine and coarse feeds and low and high speeds. As an example of the changes provided with the standard gears, it may be stated that, when employing the largest cam, there are five fine feeds between 0·0151 in. and 0·0598 in. per spindle revolution, and five coarse feeds between 0·0485 in. and 0·1920 in. With the smallest cam, the total feed range is between 0·0006 in. and 0·0080 in. Similarly, the standard gears provide four low spindle speeds between 23 r.p.m. and 62 r.p.m., and four high spindle speeds between 76 r.p.m. and 202 r.p.m. All these speeds and feeds are with the pulley shaft running at 500 r.p.m.

No tools are shown on the cross-slides in the illustrations, but it will be clear from Fig. 2 that these slides can be traversed, their movement being derived from cams. With auxiliary equipment, threading can also be performed on the machine. The equipment consists of an attachment mounted on a slide attached to the top cross-bar of the machine. The threading spindle has independent traverse, controlled by levers and cam-drums in the gearbox housing in much the same way as are the main tool slide and cross-slides. The same type of equipment is used for high-speed reaming. It may be of interest, as giving a scale to Fig. 1, to state the main dimensions of the machine: the overall length is 15 ft., the width is 6 ft., and the height 7 ft. 10 in. In spite of this considerable height, however, the tooling portion of the machine is conveniently reached and full automatic protective devices are provided. All the shafts are mounted in adjustable anti-friction bearings and splash lubrication is employed internally.

## SIX-SPINDLE AUTOMATIC LATHE.

MESSRS. THE NATIONAL ACME COMPANY, CLEVELAND, OHIO, U.S.A.

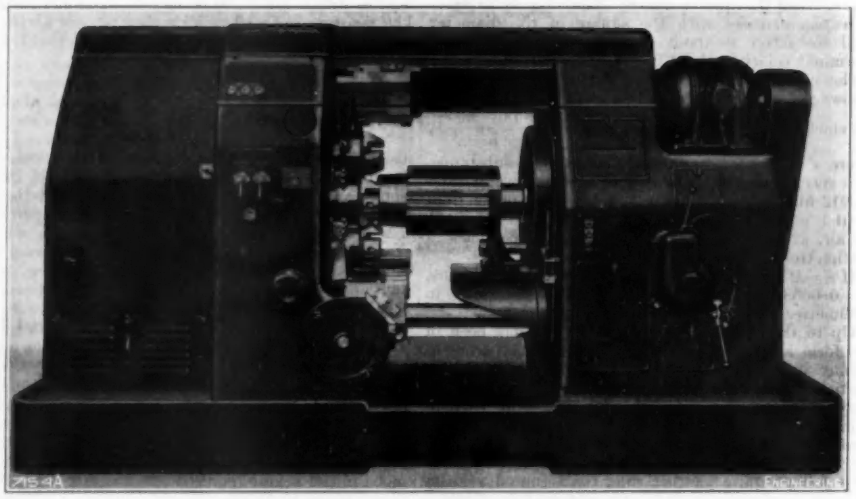


FIG. 1. 12-IN. SIX-SPINDLE AUTOMATIC LATHE.

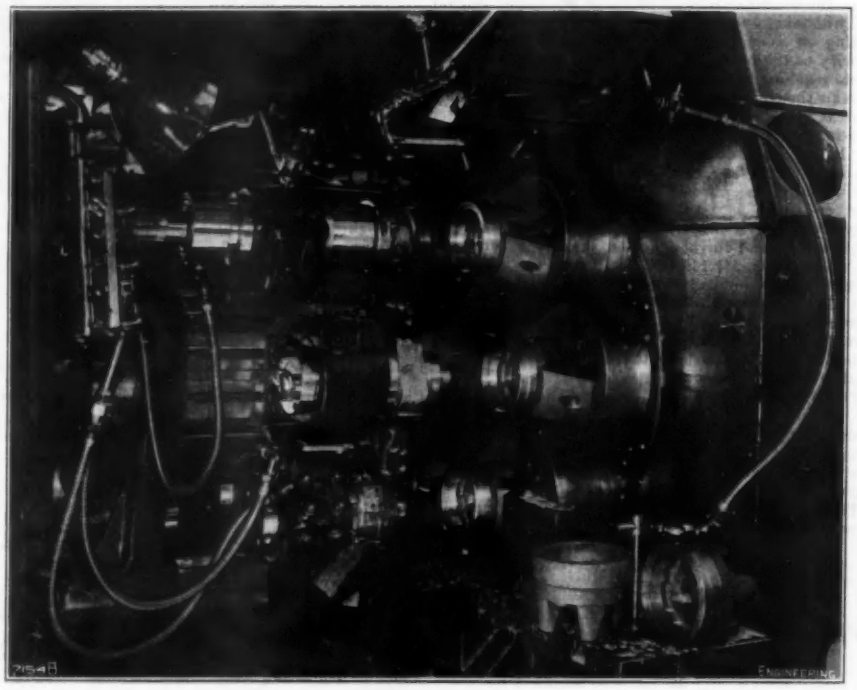


FIG. 2. MAIN TOOL SLIDE.

UNEMPLOYMENT IN THE UNITED STATES.—According to statistics issued by the London office of the Guaranty Trust Company, of New York, 32, Lombard-street, E.C.3, the estimated unemployment figures for October, in the United States, stood at 8,149,000. For the third consecutive month the total showed a decline, the figure for September being 8,196,000, and that for October, 1938, 9,241,000.

## TWIN-DISC CLUTCH FOR INDUSTRIAL APPLICATIONS.

A SIMPLE and reliable clutch for industrial applications has recently been introduced in this country by Messrs. British Twin Disc and Clarifiers, Limited, Bush House, Aldwych, London, W.C.2. This clutch, known as the Twin Disc, is made in a variety of designs and sizes, the leading features being that the friction area is exceptionally large to ensure long life and to reduce adjustments to a minimum, that there is no thrust on the crankshaft of the engine to which it is applied, that the adjustment is simple, and that the disc or discs are driven at the point of least load.

One of the clutches, known as the Power Take-Off model, is illustrated in Figs. 1 and 2, opposite. This model is suitable for application to all internal-combustion engines with standard S.A.E. flywheel-housing dimensions. It is built in sizes ranging from single-plate models, 6½ in. in diameter, to double-plate models, 18 in. in diameter. The illustrations show a double-plate clutch with 12-in. diameter plates. Such clutches are available for industrial applications up to a maximum output of 225 brake horse-power. A typical example of the application of such clutches

# TWIN-DISC CLUTCH FOR STATIONARY ENGINES.

MESSRS. TWIN DISC AND CLARIFIERS LIMITED, LONDON.

*Fig. 1.*

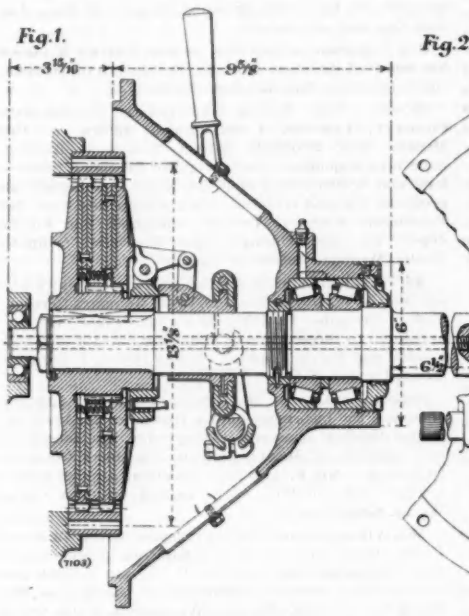
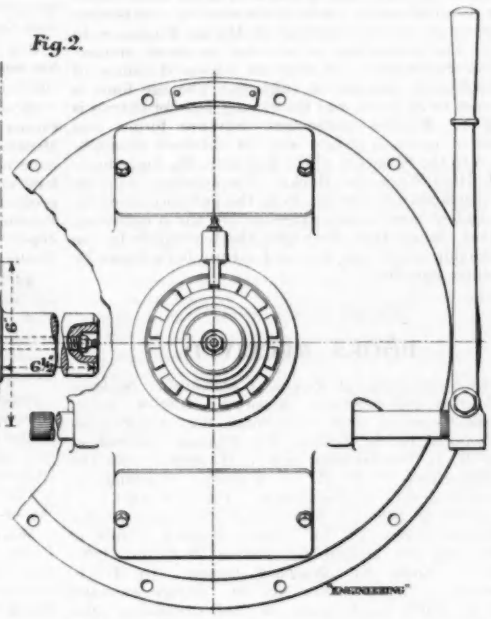



*Fig. 2.*



is in connection with multi-cylinder engines employed in oil-well pumping service, the essential requirements in this class of work being easy engine starting, smooth pick up of the load, and convenience in applying the pulley for flat or Vee-belt drive. The power take-off, constituting a self-contained unit, comprises the clutch, the bell housing, and the pulley shaft, as shown in the figures. As will be clear from Fig. 1, the clutch proper comprises three driving and two driven discs, the former being of cast-iron alloy, and the latter of steel, faced on each side with asbestos fabric. The left-hand outer disc is keyed to the end of the output shaft, and is held firmly in place by a nut. This disc constitutes the outer plate, and takes up all clutch thrust, so that, as stated, no thrust is transmitted to the engine crankshaft. The other two driving discs are free to slide on splines on the boss of the left-hand disc, while the driven discs are free to slide on splines cut on the interior periphery of a ring bolted to the flywheel. All the discs, with the exception of the left-hand one, are, therefore, free to move laterally as required. It will be observed from the figures that, contrary to the usual practice, the clutch is disengaged by a ring of springs, and engaged by four fingers in the form of toggle levers. It is claimed that the arrangement adopted gives a more accurate control of the clutch pressure, and a better graduated and more positive take-up. On the other hand, it is evident that since wear is not automatically taken up by spring extension, adjustment will be required at more frequent intervals when the clutch is relatively new. As, however, the adjustment is very easily made, this is not a serious objection in the case of industrial applications, since the equipment in such cases is almost invariably in the charge of competent mechanics. The objection might be more serious if the equipment were in charge of a non-skilled man, and it may be mentioned in this connection that this type of clutch is definitely not recommended for road-vehicle use. It will be observed from Fig. 1 that the ring carrying the toggle levers is in the form of a nut engaging with a thread cut on the boss of the left-hand disc, and to adjust the clutch, it is only necessary to rotate this ring. Hand holes are provided at the top and bottom of the clutch casing for this purpose, and no tools are required to make the adjustment. The ring is locked in position by means of the spring-loaded lock pin shown at the bottom of the ring in Fig. 1, and when the clutch is rotated to bring this pin to the top or bottom, it can be readily withdrawn by the fingers, the ring rotated, and the pin inserted in another hole. The adjustment should be such that a distinct pressure is required on the hand lever to engage the clutch.

The clutch shaft is carried in a ball pilot bearing mounted in the flywheel in the usual way, and in a double taper-roller bearing at the rear end. Particular attention has been paid to the efficient lubrication of all moving parts. In the model illustrated, two grease-gun nipples are provided, one in the top of the casing, and the other on the end of the shaft. The former feeds the main taper bearing, and the latter the pilot bearing through a hole drilled down the centre of the shaft. A branch from this passage feeds the sliding collar to which the toggle levers are linked, and a passage through the collar flange enables the same nipple to supply the bearing surfaces between this flange and the yoke ring. When it is not convenient to feed through the end of the shaft, arrangements can be made for locating the grease nipple at some other convenient point. It will be noticed from Fig. 2 that the shaft carrying the trunnion forks is extended through the casing so that the operating lever can be mounted on either end.

## NOTES ON NEW BOOKS.

*The Mechanics' Repair Shop Manual.* By HERBERT J. DYER. [Price 2*s.* 6*d.* net.] *Marking-Out for Machinists.* By CAPTAIN RICHARD TWELVETREES. [Price 1*s.* 6*d.* net.] *The Beginners' Guide to the Lathe.* By PERCIVAL MARSHALL. [Price 1*s.* 6*d.* net.] London: Percival Marshall and Company, Limited.

WHILE two of these books are revised and enlarged editions, the first one, namely, *The Mechanics' Repair Shop Manual*, appears to be a recent addition to the series of Messrs. Percival Marshall's workshop handbooks. In it, the author claims only to have put down some notes likely to be of service to those who, like himself, run their own little shops, and that with a not too well stocked tool kit; but within this limit, Mr. Dyer has produced a really helpful little work, fully illustrated by admirable sketches from his own hand, and, therefore, exactly pertinent to the text. The style may not appeal to everyone, being anything but formal, but there are no ambiguities and no padding. Moreover, it is evident that all the jobs described have actually been done; for, where difficulties arise, after a number of alternative methods of overcoming them have been suggested, a sort of "forlorn hope" is often indicated. A case in point is the freeing of a shaft from a seized white-metal bearing, the author recommending, when all other methods have failed, melting out the metal by means of a blow-lamp while the bush is still on the shaft. Presumably he has proved this method, but we feel some doubt regarding the effect of a blow-lamp on a modern alloy-steel shaft. However, this is an extreme case; in the main, the tips and wrinkles given in the book are much less drastic and, indeed, are soundly practical. There are 14 chapters, each dealing with different classes of repair, subjects touched upon including the extraction of keys; drawing-off flywheels and gear wheels, and re-metalling bushed bearings. Mr. Dyer, in short, has covered a considerable amount of ground, and his book should be of use to a wider public than that for which it was intended. As the other two books are already well known, it is sufficient to mention that both have been widened in scope, and a considerable amount of new matter and a number of illustrations added. *Marking-Out for Machinists* has been revised by Mr. Robert Hutcheson, and *The Beginner's Guide to the Lathe* by the author. Both books should be of particular service to the apprentice, improver or amateur mechanic, since they deal with basic principles often taken for granted in more ambitious works.

*Gas Charts for Steam Boilers.* By J. WEBSTER. Manchester: Emmott and Company, Limited. [Price 1*s.* net.]

THE title of this small book, which is one of the "Mechanical World Monographs," does not, perhaps, convey an adequate idea of its scope, which is really to establish a means of arriving at the performance of the different elements of a boiler, such as furnace water-walls, main tubes, superheater, economiser, air heater, etc.; or, conversely, to design a boiler, with the correct proportions of these elements, for a given performance on data derived from others of the same type. Beginning with the statement that 11 curves may be plotted on the charts representing temperatures, volumes, $CO_2$ percentages, etc., the methods of constructing and interpreting the curves are fully discussed. The matter is presented clearly and simply, and from some aspects, in a fresh manner, the distinction drawn between radiation and convection heating surface being a case in point. Although the boiler taken as an illustration is a large high-pressure one of the straight-tube sectional type, the system would appear to be applicable to other types, each class being, of course, kept distinct as a source of data. The book is likely to be most useful to those who are prepared to take the trouble to collect comparative particulars systematically. The mathematics involved in the calculations required should be manageable by the average engineer.

*Formulas for Stress and Strain.* By PROFESSOR R. J. ROARK. London: McGraw-Hill Publishing Company, Limited. [Price 18*s.* net.]

THE degree of success attainable in the design and manufacture of large and complex structures depends to a great extent on a sufficient knowledge of the distribution of stress over such complicated shapes as are associated with notched bars, curved beams, and shafts of non-circular section; but the requisite data are by no means easy to gather at short notice from records of research that are to be found only in technical and scientific libraries. Professor Roark's book should be welcome, therefore, to that wide circle of engineers who require a comprehensive collection of formulæ, combined with a well-arranged summary of what is known about the strength of materials. Care has been exercised to secure an even balance between formulæ for the structural members above-mentioned, on the one hand, and, on the other, for the stress in flat plates, the pressure induced on flat or curved surfaces by a ball or circular cylinder, and the stress produced in discs by dynamic and temperature effects. In this way the book touches most branches of engineering, including the design of aircraft, in which recourse may be had to the tabulated data on the stability of slender bars and very thin plates. There are, in addition, several numerical applications of the more important equations, and up-to-date bibliographical lists of journals and treatises which may be consulted in connection with the various questions raised in a given chapter. Professor Roark has thus brought together a mass of knowledge that may be readily adapted to the requirements of drawing offices, laboratories and engineering colleges.

*The Design of Flat Plates.* By C. C. POUNDER. London: The Draughtsman Publishing Company, Limited. [Price 2*s.* net.]

AMONG the excellent booklets prepared by the Association of Engineering and Shipbuilding Draughtsmen, that on *The Design of Flat Plates* is not the least valuable. Based on a series of articles in the *Mechanical World*, some twenty-five years ago, the first edition in its present form was published five years later in the inaugural set of papers produced by the Association. The present edition has been revised and enlarged, and covers most of the problems likely to be met with by the designer. As the title indicates, the survey is confined to flat plates, and the solution of problems in the design of dished ends or stayed surfaces must be sought elsewhere. With this limitation, an attempt is made to provide a basis for the calculation of stresses in the different forms of plate which occur in general engineering work, and to point out the salient features of good design. A useful summary of the formulæ deduced in the text is given at the end of the book. The treatment commences with the consideration of simple encastré and ribbed encastré rectangular plates, and similar plates of box section. Both plain and ribbed rectangular plates, simply supported, are next considered, and following on this, various forms of similar plate are dealt with, including flanged circular

plates. The booklet concludes with a number of general notes covering such points as the definition of encastrément, typical fractures, and a summary of the experimental work carried out by various investigators. The mathematical treatment is within the scope of anyone possessing a working knowledge of the calculus.

---

*The Elements of Sheet Metal Work.* By W. COOKSON and A. BOLD. London: The Technical Press, Limited. [Price, 6*s.*]

THE first requirement in an elementary textbook intended for sheet-metal workers, especially for the apprentices, is that it should be phrased in plain practical terms, free, so far as possible, from unfamiliar geometrical expressions. The vagueness of these to the majority of such workers constitutes an almost impenetrable barrier to an understanding of the instruction offered. It is a merit of this book that the explanations and directions given by its authors are easy to read and understand, and are supported by well-drawn diagrams. The geometrical side of the treatment is largely a study of the development of surfaces, and is set out in three stages: first, the simple cases of parallel-line development, then those effected by means of radial lines and, finally, the more general class involving the method of triangulation. In this last section, the authors have devised a simpler technique than that usually adopted, and the student should find it comparatively easy to grasp the principle. The early chapters deal with such preparatory instruction as workshop arithmetic, geometry, mensuration and pattern lay-out, by means of which the general ideas of development are advanced. After the practical geometry there follow sections describing metals and their properties and the tools, joints and simple operations used in sheet-metal work. For students, apprentices, journeymen, draughtsmen and others interested in pattern development, the book offers a handy and readable source of practical information.

---

*Metalwork.* By HUGH M. ADAM and JAMES H. EVANS. Third edition. London: Edward Arnold and Company. [Price 10*s.* 6*d.* net.]

IN recent years, instruction in metal working has come to be recognised as an essential part of a full education, so that now it appears in the curricula of elementary and secondary schools under the Board of Education, as well as in those of other public and private schools. The extensive range of the subject involves the giving of suitable instruction regarding the metals themselves, the processes by which they are prepared for the craftsman's use, and the properties which they possess or may acquire in working. The first part of *Metalwork* is devoted to this aspect of the subject. After a preliminary chapter containing much that is of moment to the instructor on the teaching and practice of school metalwork, there follows a section on the metals used in the craft-room. It contains a short history of metals and metallurgy, chapters on nature and distribution of the metallic ores, the methods of manufacture of iron, steel and the non-ferrous metals, and the properties, characteristics and workshop uses of the common metals. This section provides the background of the student's work and in the second part he passes on to the practical side, in which the tools and the processes of several branches of the craft are described and explained. The subjects dealt with include the measuring and marking-off instruments, and both hand and machine tools, their uses being clearly indicated. To the various processes which were included in earlier editions there has been added a chapter on copper working; a branch which, from the point of view of class work, possesses the advantage of lending itself to training in decorative art. Other minor additions have been made to meet the requirements of the latest syllabuses of the schools, and of the City and Guilds of London and other examinations, for which it should prove a very suitable text-book.

---

THE LATE MAJOR W. M. BAIRD, O.B.E., T.D.—We note with regret the death of Major William Merrilees Baird, which occurred suddenly at his home in Spring-gardens, Glasgow, on December 19. Major Baird, who was managing director of Messrs. William Baird and Son, Limited, bridge builders and structural engineers, Temple Iron Works, Anniesland, Glasgow, W.3, was in his 61st year and was a native of Glasgow. The son of the late Mr. William Baird, who established the firm in 1880, Major Baird had been connected with it for the past 45 years. He was for many years an officer in the Territorial Force and, during the war of 1914-1918, served as a major in the 9th Battalion Argyll and Sutherland Highlanders. He was attached to the headquarters of the 51st and 61st Divisions and, for his services, received the O.B.E., and was mentioned in dispatches. Subsequently, he was awarded the Territorial Officers' Decoration. He was a member of the Association of Bridge Builders and Structural Engineers.

## ENGINEERING TRAINING AND EDUCATION.

*Lloyd's Register Scholarship.*—The General Committee of Lloyd's Register of Shipping offers a Scholarship, valued at 100*l.* per annum and tenable for three years, to be awarded on the results of the student-membership examination of the Institute of Marine Engineers in May. The scholarship is intended to assist marine-engineering students to take an advanced course of instruction in engineering subjects. The age limit is 18 years to 23 years, and the closing date for entries is April 8. Further particulars, entrance forms, and copies of previous papers may be obtained on application to the Secretary of the Institute, 73, Amersham-road, High Wycombe, Bucks. The entrance form for the scholarship is distinct from the entrance form for the student-membership examination, and a candidate for that examination who wishes also to compete for the scholarship must complete and return both forms by the dates specified.

## BOOKS RECEIVED.

*United States National Bureau of Standards. Building Materials and Structures.* Report No. BMS30. *Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association.* By H. L. WHITTEMORE and A. H. STANG, with the collaboration of T. R. C. WILSON. Washington: Superintendent of Documents. [Price 10 cents.]

*University of Illinois. Engineering Experiment Station* Reprint Series No. 15. *Edgar Marburg Lecture of the American Society for Testing Materials,* 1939. *Stress, Strain and Structural Damage.* By H. F. MOORE. Circular Series No. 39. *Papers Presented at the Fifth Short Course in Coal Utilization, Held at the University of Illinois, May 23-25,* 1939. [Price 50 cents.] Bulletin Series No. 316. *The Effect of Range of Stress on the Torsional Fatigue Strength of Steel.* By J. O. SMITH. [Price 45 cents.] Bulletin Series No. 317. *Fatigue Tests of Connection Angles.* By PROFESSOR W. M. WILSON and J. V. COOMBE. [Price 30 cents.] Urbana, Ill., U.S.A.: The Engineering Experiment Station, the University of Illinois.

*Report on the A.S.T.M. Standard Specifications for Classification of Coals by Rank and by Grade and Their Application to Canadian Coals.* Prepared for the Associate Committee on Coal Classification and Analysis of the National Research Council of Canada. June, 1939. Ottawa: National Research Council of Canada. [Price 25 cents.]

*Journal of the Institution of Civil Engineers.* Volume 10. *November and December,* 1938, *and January,* 1939. Volume 11. *February, March and April,* 1939. Volume 12. *June and October,* 1939. London: Offices of the Institution.

*Staffordshire Iron and Steel Institute. Proceedings. Session* 1938-39. Volume LIV. Edited by DR. E. C. ROLLASON, Secretary. 14, Hemycock-road, Selly Oak, Birmingham, 29: Offices of the Institute.

*United States National Bureau of Standards. Building Materials and Structures.* Report BMS 26. *Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Company, Inc.* By H. L. WHITTEMORE, A. H. STANG and C. C. FISHBURN. [Price 10 cents.] Report BMS 29. *Survey of Roofing Materials in the North-eastern States.* By H. R. SNOKE and L. J. WALDRON. [Price 10 cents.] Washington: Superintendent of Documents.

*Jigs, Tools and Fixtures. Covering the Drawing and Design of Equipment for Practically All Modern Machine Tools.* By PHILIP GATES. Second edition, enlarged. London: The Technical Press Ltd. [Price 10*s.* net.]

*Egypt. Ministry of Public Works. Physical Department.* Paper No. 39. *Report on the Measurement of the Quantity of Dust in the Atmosphere of Cotton Ginneries.* By H. E. HURST and P. A. CURRY. Búlâq, Cairo: Publications Office, Government Press. [Price P.T. 5 or 1*s.*]

---

PANAMA-CANAL TRAFFIC.—During the year ending October 31, 1939, a total of 5,964 ships, carrying 28,845,906 tons of cargo, passed through the Panama Canal, compared with 5,486 ships, carrying 25,860,496 tons of cargo, during the twelve months ending October 31, 1938.

---

NON-PNEUMATIC TYRED VEHICLES.—When, a few years ago, the requirement of pneumatic tyres on motor vehicles was made general, vehicles and trailers which had been put on the roads with non-pneumatic tyres before January 1, 1933, were given a reprieve until January 1, 1940. The Minister of Transport, however, has now made regulations extending the period for another year.

## PERSONAL.

MESSRS. PRAT-DANIEL, LIMITED, have moved their offices permanently from High Holborn, London, W.C.1, to Dalston-gardens, Stanmore, Middlesex. The move has been necessitated by the need for more spacious premises for the firm's growing business in fans, dust collectors and air heaters.

THE CHAMBER OF SHIPPING OF THE UNITED KINGDOM has removed its offices from 28, St. Mary Axe, to Bury-court, St. Mary Axe, London, E.C.3.

MESSRS. THE BRUSH ELECTRICAL ENGINEERING COMPANY, LIMITED, Loughborough, inform us that MESSRS. THE SCOTTISH MOTOR TRACTION, LIMITED, have been appointed distributors for Scotland, Cumberland and Westmorland of Brush-Koela duo-draught gas producers for road vehicles. They will operate from their Edinburgh, Glasgow, Dundee, Galashiels and Carlisle depots and also through their associated company, Messrs. Western Motors, of Glasgow.

MR. C. A. KELLY, who has long been associated with the late MR. A. W. GOTCH BERRILL (who, we regret to record, died on December 16, 1939, after a brief illness) has been appointed to succeed him as managing director of Messrs. Gordon and Gotch, Limited, Gordon House, Farringdon-street, London, E.C.4.

MESSRS. SULLIVAN MACHINERY COMPANY, LIMITED, announce the incorporation, on December 22, 1939, of a limited-liability company taking over the sales assets and liabilities of Messrs. Sullivan Machinery Company, Grantham. MR. F. A. BIRD is managing director and the business will continue to be carried on from Grange Works, Grantham.

MR. WILLIAM JOHN TENNANT, senior partner in Messrs. Boult, Wade and Tennant, chartered patent agents, 112, Hatton-garden, London, E.C.1, has retired from practice and from his partnership in the firm as from December 31, 1939. MESSRS. WILLIAM H. BALLANTYNE, RONALD S. DOLLEYMORE, J. CAMERON RENNIE, ARTHUR ABBEY and THOMAS B. CLARK will continue to practice in partnership at the same address and under the same style.

## TENDERS.

WE have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

*Chemicals,* including carbon tetrachloride, copper arsenate and tartrate, and sodium carbonate, for the Onderstepoort Laboratory. Union Tender and Supplies Board, Pretoria; January 18. (T. 30,170/39.)

*Porcelain Insulators,* 18 oz., 3,500. General Stores Department, Town Hall, Durban, Natal, South Africa; January 19. (T. 30,183/39.)

*Magneto Generators* for the Department of Posts and Telegraphs. Union Tender and Supplies Board, Pretoria; January 25. (T. 30,207/39.)

*Copper Tubes,* ¼-in., and couplings, ferrules and stop-cocks. Water Engineer's Department, Durban, Natal, South Africa; January 19. (T. 30,180/39.)

## NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

*The Welsh Coal Trade.*—The intervention of the holidays severely curtailed the amount of business that could be concluded on the Welsh steam-coal market last week. Nevertheless, customers, both in the inland and export branches, continued to display considerable interest and as sellers generally had only limited quantities of coal to offer, a very firm tone was maintained. The supplies available for prompt delivery were again quietly offered, but as a rule, these were only of limited proportions and alternative outlets could be found without difficulty. Forward business was held in check by the difficulty in arranging stems, particularly for the more popular sorts, for some time to come. Duff coals continued to present the strongest feature of the market. Supplies of these sorts were almost completely unobtainable over some months to come, as most producers had already disposed of practically the whole of their potential outputs and prices were strongly maintained. Sized sorts were only sparingly available, while all the large varieties were well placed with outlets. Smalls, with the exception of the inferior sorts, were not so plentiful. Cokes and patent fuel, however, remained active.

*The Iron and Steel Trades.*—Operations in the iron and steel and allied trades of South Wales and Monmouthshire were well maintained last week. Numerous inquiries were circulating and with order books well filled the works were assured of brisk employment for some time to come.

## NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

*Iron and Steel.*—Inquiries in all branches of the steel and engineering trades in this district reveal that the pressure of orders is more acute. Contracts are accumulating and manufacturers are having difficulty in arranging deliveries. In the production of raw and semi-finished materials more furnaces are being put into commission to implement the record output. Producers report that sufficient tonnages of hematites, pig iron, and scrap are coming to hand, and future requirements seem assured. Rolling mills, forges, and press shops are all operating to capacity, while re-rollers are experiencing an exceptionally busy time. The demand for all types of machinery and finished engineering products shows a steady improvement. Dealers in reconditioned machinery are having difficulty in supplying the needs of customers. The run on steelworks' and ironworks' machinery has been well maintained. The position of makers of railway rolling stock shows improvement, and among the lines in satisfactory demand are wheels, axles, springs, tyres, and buffers. Business on export account is expanding. Another progressive section is that devoted to the production of steel and machinery for civil-engineering purposes. Sheffield Corporation is to extend the bio-aeration sewage plant at Blackburn Meadows, and is to place orders for paddle wheels, paddle-wheel covers, and mild-steel shafting. The call for electrical equipment has gained further strength during the past few weeks, and grinding and crushing machinery is also in demand. Sheffield-made coal crushers are in ready request, not only by British collieries, but by mining enterprises abroad. Sheffield's special-steel trade is expanding, the outputs of stainless steel, heat- and acid-resisting materials showing an increase. Local works are supplying increased quantities to machinery makers, while manganese steel is in demand by producers of points and crossings. Engineers' small tools are selling well, and factories are operating at high pressure. A bigger trade is developing in saws, files, and machine tools. Seasonal business in farm and garden tools is developing on progressive lines, and producers hope to have record sales during the next few weeks. The light foundries are operating to capacity.

*South Yorkshire Coal Trade.*—The demand for industrial coal on inland account has been more than maintained. Increased tonnages are going to steelworks generally, and small coal is in demand by electricity-generating stations. The cold weather has resulted in a stronger call for house coal. Most types of coke are in demand, particularly central-heating varieties. The export position has undergone little change.

## NOTES FROM THE NORTH.

GLASGOW, Wednesday.

*Scottish Steel Trade.*—After a long run of great activity, the various steel works in Scotland closed down for the New Year Holidays with order books full to overflowing. In several cases the stoppage has been brief because of the great necessity for steel material of all kinds. All plants have been subjected to a heavy strain during recent months, and the repair squads have had to work hard since operations ceased in order not to delay the restart, which in some cases has already taken place. Right up to the end of the year the steel makers were working at very high pressure, so urgent was the demand, and this state is already assured for many months to come. It is not possible to give any statistics regarding production, etc., but it may be stated that record output figures have been established. The year 1939 started quietly, but after the first quarter an opening-out was noticeable and a steady improvement took place as the Government's rearmament programme was unfolded. With the outbreak of war at the beginning of September, a great speed-up became necessary, and since then all plant has been taxed to the utmost to meet the heavy demand for material. Supplies of raw materials have been very satisfactory and fairly good stocks are now held generally. The different steel-consuming industries have all been extremely busy, while a fresh outlet for sheets resulted from the demand for air-raid shelters. A new scale of prices came into force at the beginning of 1939 with a reduction of from 12*s.* to 20*s.* per ton, and no change was made in the scale until the end of October, when it was found necessary to advance prices owing to increases in the cost of all materials. The advance ranged from 20*s.* to 27*s.* 6*d.* per ton, and in the case of heavy steel the increase was earmarked as a fund to meet the extra costs on imported materials due mainly to war conditions. The following are the current quotations:—Boiler plates, 12*l.* 8*s.* per ton; ship plates, 11*l.* 10*s.* 6*d.* per ton; sections, 11*l.* 8*s.* per ton; medium plates, 13*l.* 2*s.* 6*d.* per ton; black-steel sheets, No. 24 gauge, 16*l.* 2*s.* 6*d.* per ton; and galvanised corrugated sheets, No. 24 gauge, 18*l.* 12*s.* 6*d.* per ton, all delivered at Glasgow stations.

*Malleable-Iron Trade.*—In the West of Scotland malleable-iron trade the past year has not been exceptionally good, as the demand for bar iron could always be met and there were few delays in delivery. The re-rollers of steel bars, however, have been exceedingly busy for most of the year. The supply of "semies" was, on occasion, short of requirements, but arrangements were made to increase the shipments from the Continent and recent arrivals amounted to a large tonnage. Order books are very full, and as stocks of raw materials are now satisfactory, the prospects are exceedingly good. The current quotations are as follows:—Crown bars, 12*l.* 15*s.* per ton; re-rolled steel bars, 12*l.* 19*s.* per ton; No. 3 bars, 12*l.* 17*s.* 6*d.* per ton; and No. 4 bars, 12*l.* 12*s.* 6*d.* per ton, all for home delivery.

*Scottish Pig-Iron Trade.*—The Scottish pig-iron trade has been extremely active during the past year, and for many months there has been a steady pressure for deliveries of both hematite and basic iron. As the steel makers were experiencing a scarcity of scrap, their demands for pig-iron increased and the output of the 14 furnaces in blast has been going rapidly into consumption. The demand for foundry grades of iron has not been so constant, but the outlook is better. The following are to-day's market prices:—Hematite, 6*l.* 4*s.* 6*d.* per ton, and basic iron, 5*l.* 1*s.* 6*d.* per ton, both delivered at the steel works; foundry iron, No. 1, 5*l.* 12*s.* per ton, and No. 3, 5*l.* 9*s.* 6*d.* per ton, both on trucks at makers' yards.

*Shipbuilding.*—The past year has been one of great activity in the Scottish shipbuilding industry. The yards generally were very short of orders for ships for the mercantile service in the early part of 1939, but when the Government announcement of assistance was intimated in March, there was a rush of orders for cargo vessels, and since then the industry has been very active.

## NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

*General Situation.*—Iron and steel producers have heavy order books and in some cases have to keep plant running at capacity to comply with customers' requirements. Pressure for delivery continues mostly for material for war needs, but makers are not without hope of gradually providing increasing tonnage for general industrial purposes. Usual buyers are in the market and would readily enter into substantial contracts for reasonably early delivery.

*Cleveland Iron Trade.*—While stocks of Cleveland pig are still low and prospect of resumption of regular output continues remote, foundry owners are able to obtain a little local iron suitable for their needs and supplies coming to hand from the Midlands quite cover requirements. Prices named for odd parcels of Continental iron, delivered here, are over 20*s.* per ton above values of home products and are unattractive to firms that, in the past, have made extensive use of products from abroad. Merchant business is light. Second hands have a little foundry iron to export for which they have obtained licence and despatch of cargoes is slow. Fixed prices of Cleveland pig remain on the basis of No. 3 quality at 108*s.*, delivered within the Tees-side zone.

*Hematite.*—Orders for East Coast hematite iron are difficult to place, though production is large and tonnage accumulations at makers' yards are heavy. The substantial output is insufficient for current needs and stocks are decreasing rather considerably. Quantities of iron stored—together with maintenance of make—are confidently believed to be ample for requirements very well ahead, but producers have adopted a cautious policy by practically withdrawing from the market for the present. Requirements of their own consuming departments are large and unlikely to diminish, while users dependent on the market for supplies are taking full contract deliveries. Buyers are well covered but are anxious to make further provision for needs ahead and are seeking to make new forward contracts. Stabilised quotations keep at the equivalent of No. 1 grade of hematite at 124*s.* 6*d.*, delivered to North of England areas.

*Basic Iron.*—All the make of Tees-side basic iron continues to pass into direct use at producers' adjoining steelworks and the quotation of 101*s.* 6*d.* is nominal.

*Foreign Ore.*—Users of foreign ore are not badly placed as regards supplies. Imports are on a more satisfactory scale than expected and merchants consider that arrivals are likely to be more regular than of late.

*Blast-Furnace Coke.*—Durham blast-furnace coke, of good medium quality, keeps at 29*s.* 2*d.* at the ovens, but there is no pressure to sell, and as users have made extensive provision for requirements and are not eager to buy, there is little business passing.

*Manufactured Iron and Steel.*—Semi-finished and finished iron and steel firms have a lot of work on hand. Producers of semies are delivering increasing tonnage to re-rollers, who are also receiving larger supplies from the Continent. There is greater activity at finished-iron works than for a considerable time, and finished steel producers are fully employed. Sheet makers are busy on ordinary contracts, execution of which has been delayed by necessity of attention to Government orders. Manufacturers of shipbuilding material are heavily sold over several months, and pressure for delivery of heavy steel is unabated. For home trade, soft steel billets are quoted 8*l.* 7*s.* 6*d.*; hard steel billets, 9*l.* 10*s.*; steel ship, bridge and tank plates, 11*l.* 10*s.* 6*d.*; joists and sections, 11*l.* 8*s.*; boiler plates, 12*l.* 8*s.*; black sheets No. 24 gauge, 16*l.* 2*s.* 6*d.*; and galvanised corrugated sheets, No. 24 gauge, 18*l.* 12*s.* 6*d.*

*Scrap.*—Shortage of iron and steel scrap is being relieved by arrival of material from overseas.

## NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Lancashire Branch:* Saturday, January 6, 3 p.m., The Engineers' Club, Manchester. "Gating and Pouring Temperatures in the Non-Ferrous Foundry," by Mr. J. Laing. *Lancashire Branch, Burnley Section:* Tuesday, January 9, 7.30 p.m., The Municipal College, Ormerod-road, Burnley. "A Foundryman Wants to Know," by Mr. A. Jackson. *Scottish Branch:* Saturday, January 13, 3.30 p.m., The Royal Technical College, George-street, Glasgow. "Cast Iron for Modern Engineering Applications," by Mr. T. Tyrie.

INSTITUTION OF THE RUBBER INDUSTRY.—*London Section:* Monday, January 8, 7.15 p.m., The Northumberland Rooms, Northumberland-avenue, W.C.2. Film Evening. (i) "From Tree to Factory." (ii) "De-Icers for Aircraft." (iii) "Making of a Swan Pen." (iv) "Cornish Pyramids." (v) "The Material of Infinite Uses."

BRADFORD ENGINEERING SOCIETY.—Monday, January 8, 7.30 p.m., The Technical College, Great Horton-road, Bradford. "Lubricants versus Wear, and Conditions versus Lubricants," by Mr. G. H. Thornley.

INSTITUTION OF AUTOMOBILE ENGINEERS.—Tuesday, January 9, 6 p.m., The Institution of Electrical Engineers, Savoy-place, Victoria-embankment, W.C.2. General Meeting. "Works Organisation," by Mr. Cecil Kimber. *Luton Centre:* Tuesday, January 9, 7.30 p.m., The George Hotel, Luton. Informal Discussion on "The Scope for Developing Lighter Cars," to be opened by Mr. Maurice Platt. *Coventry Centre:* Tuesday, January 9, 7.30 p.m., The Geisha Café, Coventry. General Meeting. "The Instrumental Attack on Automobile Noise," by Dr. D. B. Foster.

INSTITUTION OF PRODUCTION ENGINEERS.—*Birmingham Section:* Tuesday, January 9, 7 p.m., The James Watt Institute, Birmingham. Film Evening. (i) "The Production of Steel for Heavy Forgings." (ii) "Modern Steelcraft." (iii) "Staybright Corrosion Resisting Steel." With commentary by Mr. M. Sewell. *Luton Section:* Tuesday, January 9, 7.30 p.m., George Hotel, Luton. "The Manufacture of Basic Pig Iron and Basic Steel," by Mr. J. A. Thornton. *Edinburgh Section:* Saturday, January 13, 3 p.m., The North British Station Hotel, Edinburgh. Informal Discussion.

ILLUMINATING ENGINEERING SOCIETY.—Tuesday, January 9, 6 p.m., The E.L.M.A. Lighting Service Bureau, 2, Savoy-hill, W.C.2. General Meeting. "Discomfort Glare in Lighted Streets," by Mr. R. G. Hopkinson.

AIR RAID PROTECTION INSTITUTE.—Tuesday, January 9, 8 p.m., The Royal Society of Arts, John-street, Adelphi, W.C.2. General Meeting. "Public Basement Shelters: Practical Experience in a Metropolitan Borough," by Mr. C. F. de Steiger.

INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, January 11, 12.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Ordinary Meeting. Formal business only to be transacted.

INSTITUTION OF MECHANICAL ENGINEERS.—*Scottish Branch:* Thursday, January 11, 7.15 p.m., The Royal Technical College, Great George-street, C.1. Thomas Hawksley Lecture: "A Review of Forty Years' Development in Mechanical Engineering Plant for Power Stations," by Sir Leonard Pearce.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, January 12, 6 p.m., The Mining Institute, Newcastle-upon-Tyne. Lecture: "The Application of the Photo-Electric Cell in Industry," by Mr. J. B. Kramer.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, January 12, 6.30 p.m., 39, Victoria-street, Westminster, S.W.1. Ordinary Meeting. "The Engineer and Salesmanship," by Mr. R. G. Williams.

# ROAD AND RAILWAY BRIDGE OVER THE STORSTROM, DENMARK.

(*For Description, see Page* 4.)

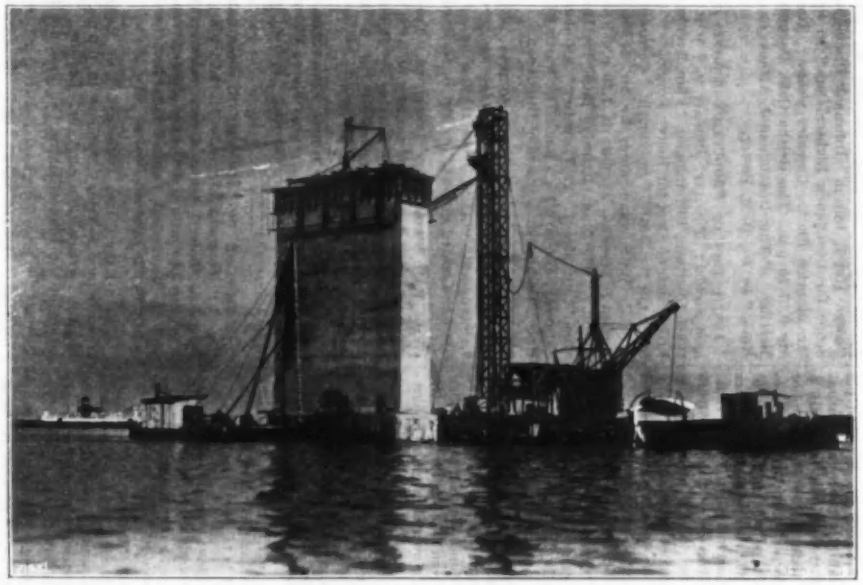


FIG. 13. HIGH-LEVEL CONCRETING PLANT.

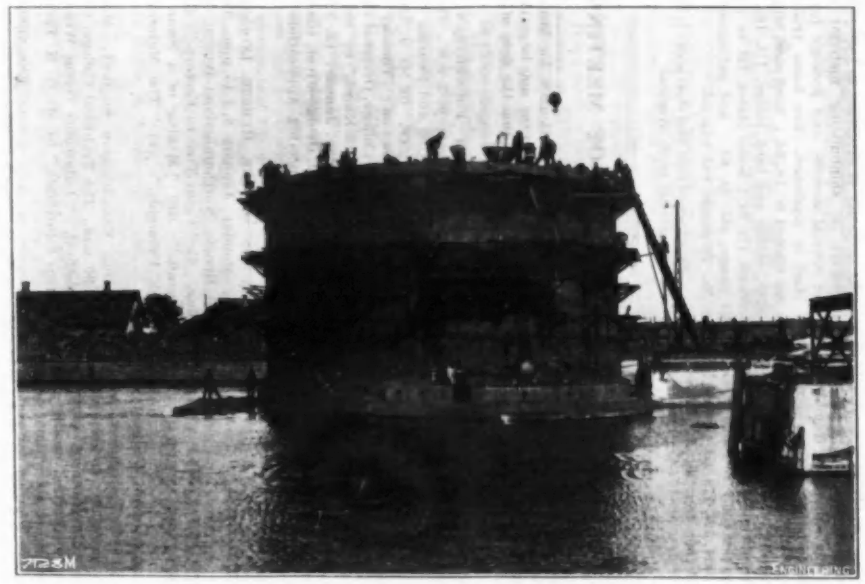


FIG. 14. EXTERNAL-TYPE FLOATING UNIT.

FIG. 15. APPROACH SPAN DURING ERECTION.

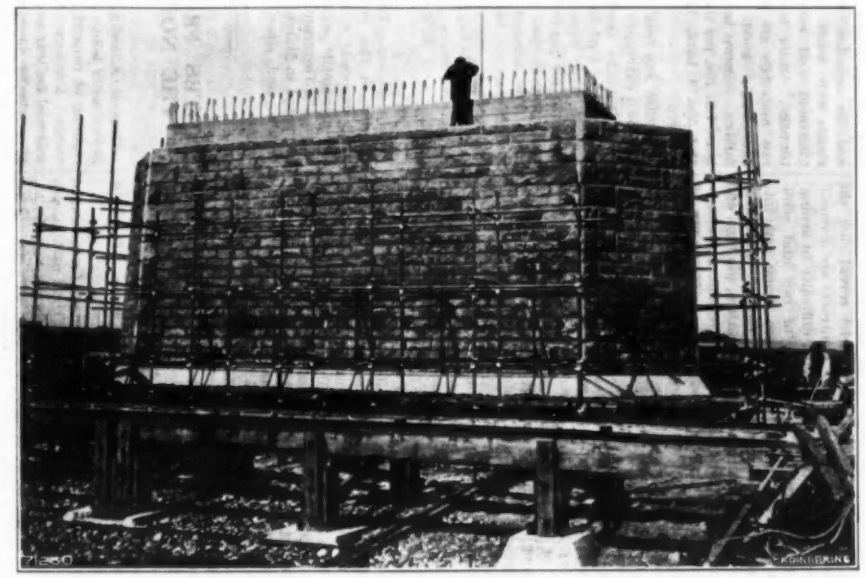


FIG. 16. MIDDLE BODY OF PIER.

UNIV. OF MICH.



# ROAD AND RAILWAY BRIDGE OVER THE STORSTROM, DENMARK.

(*For Description, see Page 4.*)

*Fig.2.*

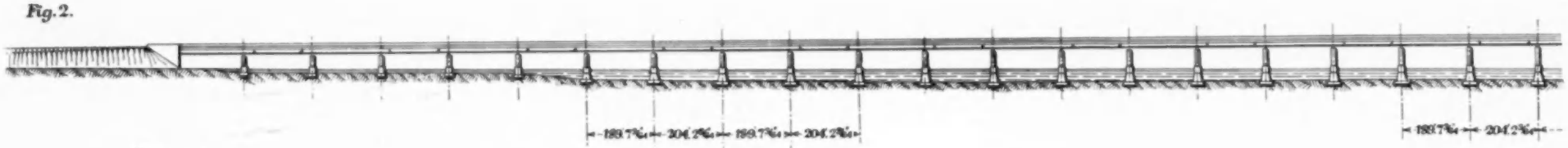



*Fig.3.*

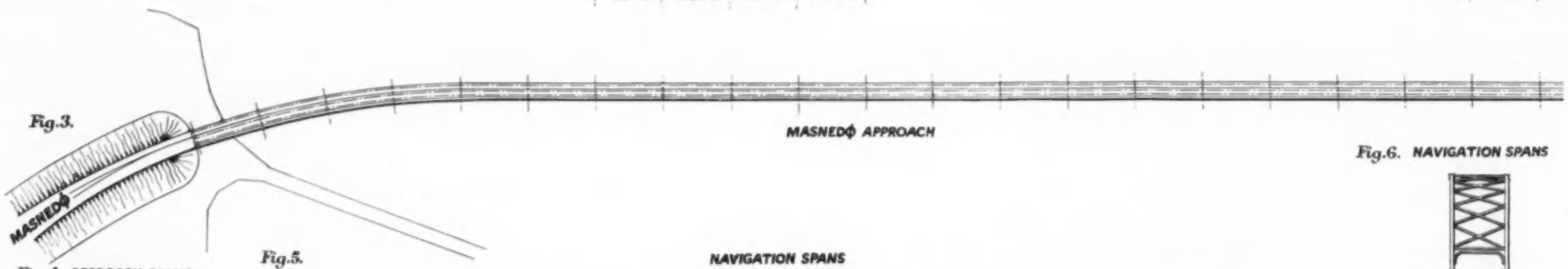



*Fig.4. APPROACH SPANS*

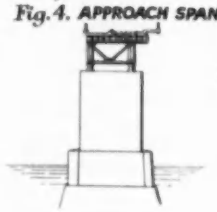


*Fig.5.*

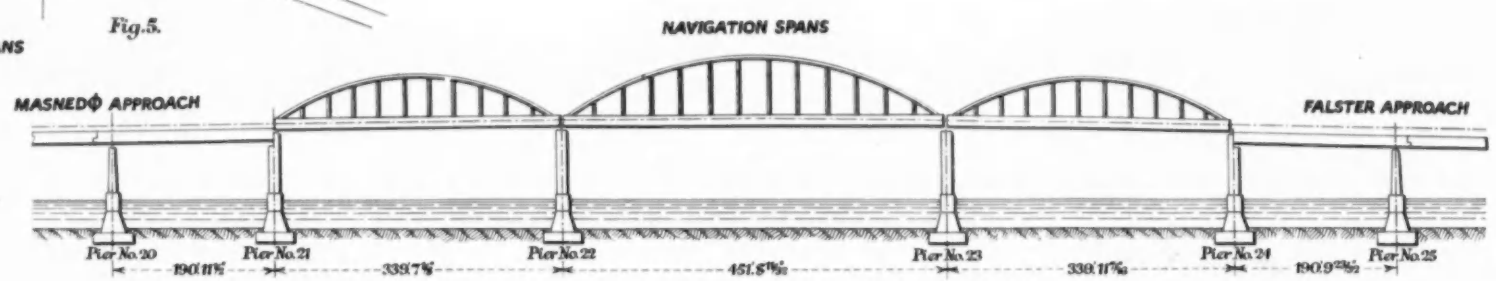



*Fig.6. NAVIGATION SPANS*

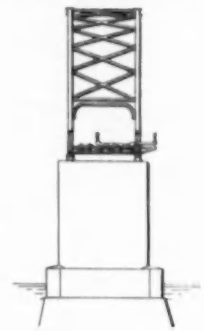


*Fig.7.*

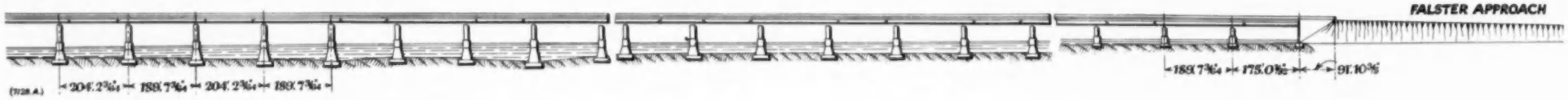



*Fig.9.* **SECTION AA**

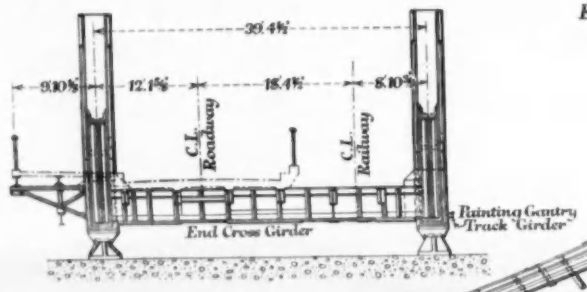



*Fig.8. HALF OUTSIDE ELEVATION*

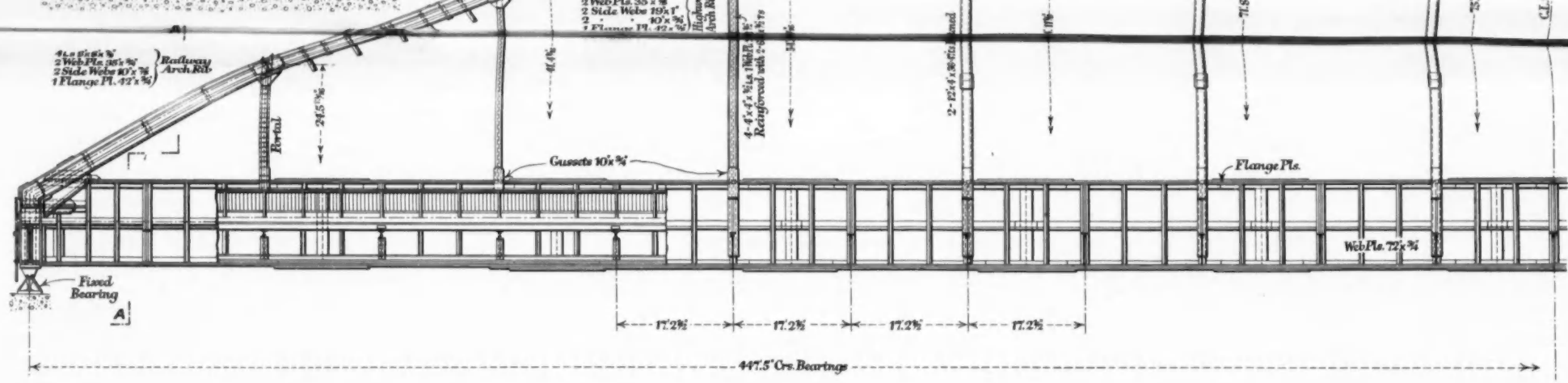



Fig. 10.

HALF PLAN OF DECK

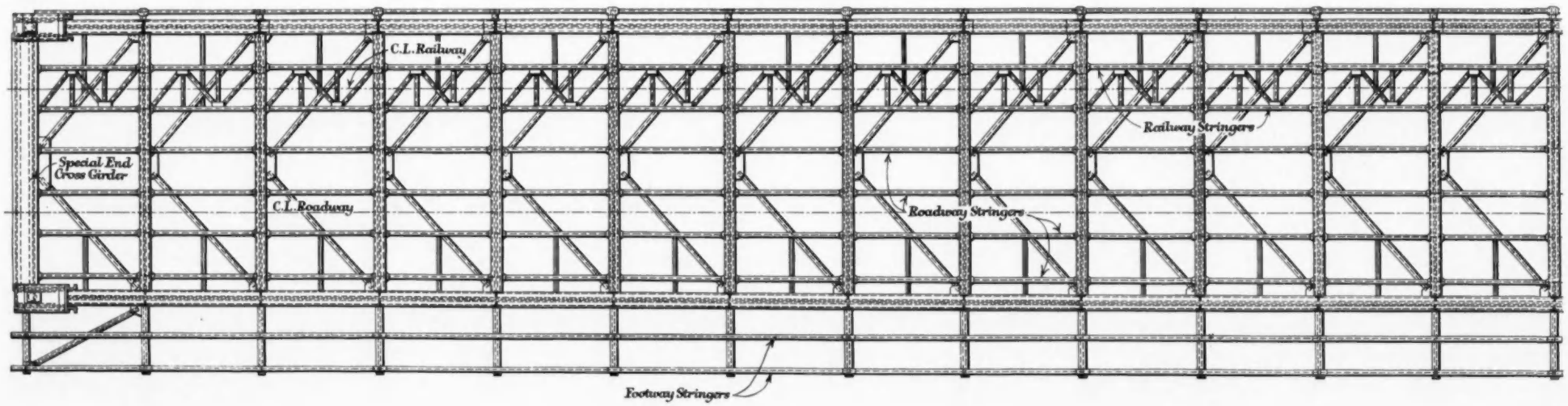
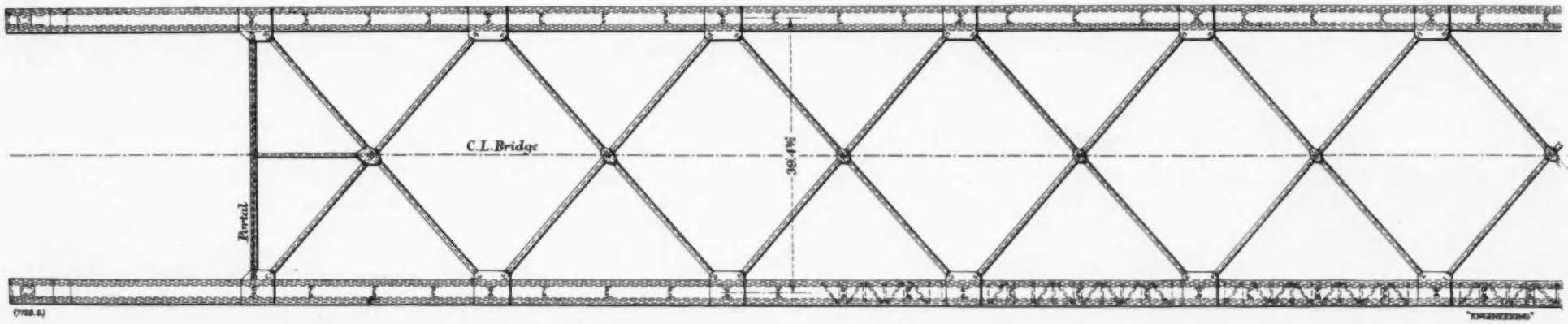



Fig. 11.

HALF PLAN OF TOP LATERALS




UNIV. OF MICH.

# ENGINEERING.

**Offices for Publication and Advertisements, 35 & 36, Bedford Street, Strand, London, W.C.2.**

**We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices and that no connection exists between this Journal and other publications bearing somewhat similar titles.**

TELEGRAPHIC ADDRESS } "ENGINEERING," LESQUARE LONDON.

TELEPHONE NUMBER—TEMPLE BAR 3663 (2 lines).

## SUBSCRIPTIONS, HOME AND FOREIGN.

"ENGINEERING" may be ordered from any newsagent in town and country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months (or for six or three months, *pro rata*), payable in advance :—

| | | | |
|---|---|---|---|
| For the United Kingdom | £3 | 5 | 0 |
| For Canada— | | | |
| Thin paper copies | £2 | 18 | 6 |
| Thick paper copies | £3 | 3 | 0 |
| For all other places abroad— | | | |
| Thin paper copies | £3 | 3 | 0 |
| Thick paper copies | £3 | 7 | 6 |

Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

## ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines, or under, and one shilling per line up to one inch. The line averages six words. When an advertisement measures an inch or more the charge is 12*s.* per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns, of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but cannot be guaranteed.

## TIME FOR RECEIPT OF ADVERTISEMENTS.

**Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of Publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The proprietors will not hold themselves responsible for blocks left in their possession for more than two years.**

All accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

## TEMPORARY ADDRESS.

**For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.**


## CONTENTS.


| | PAGE |
|---|---|
| Load Tests of a 4,000-kW Combustion Turbine Set (*Illus.*) | 1 |
| The Storstrom and Masnedsund Bridges, Denmark (*Illus.*) | 4 |
| Terminal Velocities | 6 |
| Six-Spindle Automatic Chucking Lathe (*Illus.*) | 8 |
| Twin-Disc Clutch for Industrial Applications (*Illus.*) | 8 |
| Notes on New Books | 9 |
| Engineering Training and Education | 10 |
| Books Received | 10 |
| Personal | 10 |
| Tenders | 10 |
| Notes from the South-West | 10 |
| Notes from South Yorkshire | 11 |
| Notes from the North | 11 |
| Notes from Cleveland and the Northern Counties | 11 |
| Notices of Meetings | 11 |
| Retrospect | 13 |
| Engineering Centenaries in 1940 | 14 |
| The Organisation of Munition Supplies | 14 |
| Notes | 15 |
| The Engineering Outlook | 16 |
| Sudden Discharge of Air from a Pressure Vessel (*Illus.*) | 17 |
| *Letter to the Editor.*—The Kadenacy System of Scavenging | 19 |
| Universal Milling Attachment | 19 |
| The Late Mr. William Barton Worthington | 19 |
| The Late Mr. A. H. G. Fokker | 19 |
| Labour Notes | 20 |
| Portable Grinding and Lapping Machine for Tungsten-Carbide Tools (*Illus.*) | 21 |
| Electric Welding as An Integral Part of Structural Design (*Illus.*) | 21 |
| Portable Electric Generating and Pumping Plant (*Illus.*) | 25 |
| The Classification of Commercial Coppers | 25 |
| "ENGINEERING" Patent Record (*Illus.*) | 26 |

*One Two-Page Plate.—ROAD AND RAILWAY BRIDGE OVER THE STORSTROM, DENMARK.*



# ENGINEERING

*FRIDAY, JANUARY 5, 1940.*

VOL. 149. No. 3860.


## RETROSPECT.

ALTHOUGH Britain has been at war for only four months of the year that has gone, the shadow of war has darkened the whole twelve. Spain, China, Czechoslovakia, Albania and Poland felt its full force before Britain and France together made their stand. Throughout those first eight months every newspaper contained fresh warlike reports, every wireless bulletin thrust upon the ear the tales of harryings and burnings and slayings that the eye might have missed ; until the actual declaration of a state of war with Germany came almost as a relief, for to know the worst is seldom as bad as the anticipation of it. Admittedly, that philosophic reflection was not much in mind on Sunday morning, September 3, when the unexpectedly long silence which followed the Prime Minister's broadcast announcement was broken by the first "warbling note" of air-raid sirens—a touch of sheer melodrama that will assuredly live in history ; yet, in a few more hours, even that incident was merely one more confirmation of the same broad truth, and within a week the nation had settled down to the prosecution of the "engineers' war" that earlier events in Europe had so clearly prognosticated.

If the subsequent events have completely falsified many expectations (including, doubtless, some on which the enemy had confidently counted), the credit should not be ascribed entirely to chance. Not all of the lessons of the last war had been taken to heart, but the nearness to war in the previous year was a powerful remembrancer, and the ordered smoothness with which the fighting services changed from a peace to a war footing, and the evacuation of the children and other non-combatants was effected from the vulnerable cities and industrial areas, showed that the warning of the 1938 crisis had not gone unheeded. In other respects, however, there is still evidence enough that the British people in general do not naturally tend to a military habit of mind, as do the Continental nations with a long tradition of universal military service. There is still an air of improvisation about many of the schemes for national co-ordination which military necessity dictates, and, in consequence, a certain amount of wasted effort, of failure to make the best use of available material, and of inevitably enhanced cost, largely due to reluctance to interrupt the normal routine of peace-time activities : the "business as usual" attitude which is so marked a national trait, and which is so liable to be misinterpreted by foreign observers.

In some particulars, nevertheless, there is reason to suspect that precautionary measures have been overdone. Restrictions on railway travel must be regarded as inevitable when large troop movements are in progress, but many of the inconveniences might have been avoided. Steps to prevent the sending of unauthorised messages by cable and wireless are no more than elementary commonsense ; yet the ban on the use of recognised and old-established cable addresses, the authenticity of which could be easily checked by reference to published lists which are in any well-stocked library, is a considerable handicap and a material surcharge on the normal expense of commercial communications. The tribulations initially imposed by the defective organisation of the Press censorship are fairly common knowledge, and although subsequent reorganisation has removed many of the shortcomings, the recollection of them is a constant reminder of the relative ease with which they might have been avoided at the outset had the necessary executive authority been in more experienced hands.

It may be questioned, indeed, whether the civil-servant type of mind is the best qualified to deal with emergency organisations not directly analogous in their functions with the operation of Government departments. Officials trained in the atmosphere and traditions of well-ordered departments, bound by established rules of procedure and absorbed in duties which are not subject to sudden and fundamental variation, cannot be expected to display, in the direction of quasi-industrial operations, quite the same qualities as men whose lives have been spent in actively wrestling with such problems, and whose livelihood has depended upon solving them quickly and efficiently by the exercise of their own judgment. Incidentally, the "100-per cent." business man is hardly more happy in the departmental atmosphere. *A chacun son métier.*

The early stages of the present war were notably different from those of the last, in the efforts which were made to avoid the wasteful employment of professional skill, and very considerable use has been made of the Central Register in making the numerous technical appointments necessitated by the rapid expansion of munitions production. Here again, however, the original intentions can hardly be said to have fructified to the fullest extent. Cases have occurred of candidates, nominated for urgent departmental appointments by the Register, in collaboration with the advisory panel representing the technical institutions, being kept waiting for long periods by the department concerned, with no knowledge of the fate of their applications, or whether they were being considered at all. Delays of this kind, of course, are in no way attributable to the operation of the Register itself by the Ministry of Labour and, undoubtedly, it has functioned promptly and with reasonable efficiency in very many cases ; but there is a widespread feeling that the Ministry of Labour is not the most suitable organisation to deal with the higher grades of professional appointments, and that a cardinal weakness was introduced by the insistence that all such appointments by Government departments must be made through its agency.

An added weakness is the absence of any provision for utilising the services of competent volunteers, of British nationality, who happened to be employed in foreign countries. The official channel for applications of this kind from Empire countries is through the local British Consul, but in the case of foreign countries, according to our information, instructions appear to have been given to consular officers that no such applications are to be forwarded. There may be good reason for thus stopping at the source applications from individuals whose qualifications cannot be readily checked, but this does

not apply to fully competent technical men, particulars of whose careers and special aptitudes are traceable through the records of engineering institutions; and it only leads to attempts to short-circuit the established means of selection.

Where the development of national resources has been mainly directed by the executive heads of the industries concerned, the rapidity of expansion has fully justified this policy. What may be the percentage increases of output, in relation to the optimum figures in time of peace, of such essentials as aircraft and engines, motor vehicles, guns and ammunition, are details not likely to be disclosed until after the war; but some indication is afforded of part of the war-time effort of the heavy industries by the estimate, published recently in *Lloyd's List*, that the home production of steel, on a basis of 95 per cent. of available furnace capacity, is at a rate not less than 14,100,000 tons per annum, or some 45 per cent. more than the highest output during the last war. While the production of the larger industries and firms has been thus increased, however, there are still many smaller firms which find difficulty in obtaining a sufficiently steady flow of work. Recently, strong representations have been made to the Service departments to make a fuller use of this reserve of productive capacity, and it is satisfactory to note that the comparative stagnation which some of them have experienced is being somewhat alleviated by the placing of direct orders. These small firms represent an important asset in the essential duty of maintaining the flow of British export trade. At one period there seemed reason to fear that the Government, in its pre-occupation with war efforts, tended to neglect this vital factor in the national economy and was inclined to let foreign trade take care of itself.

A welcome assurance that this policy, or lack of policy, did not represent the Government's opinion or intention was given by Mr. Oliver Stanley, M.P., the President of the Board of Trade, in a recent interview. In it the point was emphasised that manufacturers would be performing a national service by developing exports by every means in their power, even at the temporary expense of their home trade and the internal distributive organisations which have been built up to deal with it. Naturally, the need for manufactured exports to serve as payment for munitions and other goods purchased from abroad was stressed; but, while recognising this need, and the inevitability of a certain amount of disorganisation in the normal wholesale and retail distributive trades, we incline to the view that the limitation of internal consumption of home-manufactured products is a principle which should not be pressed too far. Only by trading transactions can the nation expect to find the revenue that is being and, for generations to come, will be needed to pay for the colossal expenditure which this war entails—already of the order of 6,000,000*l.* per day, on the authority of the Chancellor of the Exchequer; and, as a great part of this revenue must continue to come, in effect, from what is virtually a turn-over tax, although we describe it as an income tax, no opportunity should be neglected to maintain and increase the turn-over on which the tax is collected, provided that this does not react definitely to the nation's disadvantage. A due regard for the future also requires that no potentially productive business should be allowed to languish to the point of extinction as a result of official apathy towards the fate of undertakings which may seem insignificant when measured by the scale of present Government operations.

## ENGINEERING CENTENARIES IN 1940.

ALTHOUGH, under the conditions now prevailing, it may be presumed that centenary celebrations of even the most important events or outstanding men will be much curtailed or entirely omitted, there is no reason why attention should not be drawn to the men whose memories, in happier circumstances, would have been honoured. In the following notes, therefore, we recall the names of some of the men of science, the inventors and the engineers whose centenaries occur this year. In our columns there are few famous mathematicians more frequently mentioned than the Frenchman Poisson, who died on April 25, 1840, at the age of fifty-eight. Simeon Denis Poisson, to give him his full name, was one of the group of great mathematicians and physicists gathered together in Paris in Napoleon's day. Lagrange, Laplace, Legendre, Fourier and Fresnel were among his contemporaries. From the day that Poisson, as a youth of eighteen, entered the Ecole Polytechnique, until he died, his life was one of unceasing labour. He wrote 300 memoirs, and his treatise on mechanics was a standard work for advanced students.

France has always been able to boast of eminent mathematicians and a great forerunner of Poisson was Vieta, the greatest of sixteenth-century algebraists, who was born in 1540 and died in 1603. Vieta's contemporaries in this country were Napier, of logarithm fame, who was born in 1550, and William Gilbert, the father of electrical and magnetic science. The year of Gilbert's birth is usually given as 1540, and he died in the same year as Vieta. After Galileo had read Gilbert's *De Magnete*, he wrote, "I do not doubt that, in the course of time, this new science will be perfected by new observations, and by true and cogent demonstrations. But the glory of the first inventor will not be diminished thereby"; and Dryden afterwards wrote, "Gilbert shall live till loadstones cease to draw Or British fleets the boundless ocean awe!" The investigations of Poisson, Vieta or Gilbert were not undertaken primarily for the benefit of industry, nor were the earlier researches of the German physicist, Ernst Abbe (1840-1905); but when Abbe, as a professor at Jena, joined forces with Carl Zeiss, everything he had done and afterwards did was of immense importance to the German optical and scientific instrument trade. Sir Richard Glazebrook once spoke of Abbe's work as the most striking example of the way in which progress depends on the co-operation of science and experience.

In a different category from those already mentioned, but also in the ranks of the pioneers, were Henry Cort, the bicentenary of whose birth falls in this year, and Sir Robert Seppings, who died in 1840, after having risen from a shipwright's apprentice to Surveyor of the Navy. Seppings introduced improvements of note into the construction of the old "wooden walls" and for this and his papers on warship construction, the Royal Society awarded him the blue riband of science, the Copley Medal. He is the only naval architect to have been so honoured. Of Cort, who developed the rolling of wrought iron, we know only too little, but his patents of 1783 and 1784 will ever remain landmarks in the story of the iron industry. Another famous name is that of Montgolfier. Jacques Etienne Montgolfier was born in 1745 and died in 1799; his elder brother, Joseph Michael, was born in 1740 and died in 1810. Together, they gave the world the balloon. It was first used in war in 1794, and to-day it is being used for the same purpose, but on a vastly extended scale.

Of the men born a century ago, there are, first, John Boyd Dunlop, the man of one invention, and Sir Hiram Maxim, the man of many inventions. Then mention may be made of the two astronomers, Lord Rosse (1840-1908), elder brother of Sir Charles Parsons, and Sir Robert Ball (1840-1913), who was both astronomer and mathematician. The most eminent engineer born in 1840 was, undoubtedly, Sir Benjamin Baker, who is one of the great engineers of this country to be commemorated in Westminster Abbey. At the age of twenty-seven, Baker, then an assistant to Sir John Fowler, contributed to the columns of ENGINEERING a series of articles on "Long-Span Bridges,"* and it was in these that he discussed the possibility of the cantilever type of bridge, with a central supported girder, a type so happily adopted afterwards by Fowler and himself for the Forth Bridge. Another early assistant of Fowler was James Dredge (1840-1906), who, for over thirty years, was associated with the late Dr. W. H. Maw in the conduct of ENGINEERING. Dredge was a direct link with D. K. Clark, Zerah Colburn and Alexander Holley, and it was at the request of the American engineers that, in 1890, he delivered the address at the inauguration of the bust of Holley in Washington-square, New York.

* See ENGINEERING, vol. iii, page 250, *et seq.* (1867).

## THE ORGANISATION OF MUNITION SUPPLIES.

AN inevitable concomitant of war, at least in modern times, is a greater or less disturbance of the normal life in the fighting countries. In industry the character of the output has to be changed and the ordinary machinery of production and distribution are upset, since, instead of there being a multitude of consumers of more or less equal importance, one customer—the nation in arms—predominates and must take precedence of all the others. To effect the changes necessary to deal with this situation and so to carry on the war as efficiently as possible is not easy, as is shown by the history of the European War of 1914-18. Then, in addition to the fact that the necessity for such a change was hardly realised, it was not appreciated that profound adjustments were essential in the industrial machine. As a result, many mistakes were made and much money and life were wasted. This time, it is to be hoped that we have learnt from past weaknesses and that the supply of material of all kinds to our fighting forces is being so organised that, both in quantity and quality, it will play its full part in achieving victory.

Exactly what is being done in the attempt to bring this end about was explained by the Minister of Supply, the Rt. Hon. Leslie Burgin, at a conference held in London last week. It may be recalled that the primary object of the department over which Mr. Burgin presides, and which was formally set up last August, is the supply of all the great variety of munitions, using the term in its widest sense, required by the Army. In addition, it co-operates with the Admiralty and Air Ministry in the supply of arms and ammunition, and with other departments in the supply of machine tools and other "common user" articles. Further, it has assumed responsibility for much related design, inspection, research and experimental work and controls a number of establishments in which actual manufacture is carried out. The Ministry itself is divided into a number of departments. These, in turn, are sub-divided into a number of directorates, each of which is responsible for planning the capacity of the country to produce a certain article or group of articles. Demands for these articles are then allocated between this productive capacity in the way that seems most desirable. An important further duty is to determine whether the capacity available is sufficient or should be increased either by building new or extending existing factories. After contracts have been placed the progress of manufacture is watched and inspection is undertaken. Finally, the costs are worked out. In carrying out this work, the assistance of both employers and employed has been enlisted, and in the engineering industry area committees have been formed for advisory purposes.

An even more important part of the Ministry's work is the control of raw materials. This is effected by a special department, which is responsible for the control of all raw materials required by the country's industries, with the exception of food, coal and oil. These exceptions are, of course, controlled by other departments. In assuming this responsibility, the Ministry of Supply has a triple task to perform: to ensure that available supplies of raw materials are used to the best advantage; to see that when supplies cannot be replenished by the normal processes of trade some alternative source is tapped; and, finally, to make certain that reasonable prices obtain. One major effect of the war on the home front has been, of course, an increased demand for certain commodities, combined, not infrequently, with an interruption of normal supplies. If they had been allowed to exert their influence unchecked, the inevitable effect of these influences would have been an increase in price and fierce competition among those desirous of obtaining supplies.

During the last war attempts were made to deal with this state of affairs by a system of priorities but, as ultimate experience proved, this had many disadvantages, the principal of which was that it did not attain the desired end. In substitution for this arrangement, therefore, a system of control has been set up in a number of trades, the extent and nature of which varies with the circum-

stances, though, broadly speaking, it involves a restriction on the sale or use of the material concerned and the imposition of a maximum price. For instance, in the case of aluminium, a rigid control of use is imposed and supplies for other than service needs are largely withheld. In all cases, the purchases are made by the Ministry in bulk, with the result that favourable prices have been obtained and, as regards the consumer, steps are being taken to keep costs down to a level which will not hamper either home or foreign markets.

The account of his stewardship given by Mr. Burgin, and covering the four months that it has been in existence, disclosed results which must be startling to anyone less accustomed to dealing with large figures than astronomers and Treasury officials. Since the outbreak of war, orders to a value of 234,000,000*l.* have been placed, exclusive of contracts of a continuing character for raw materials. Of this huge sum, 73,000,000*l.* was accounted for by raw materials, 45,000,000*l.* by vehicles, 13,000,000*l.* by machine tools, and 12,000,000*l.* by optical and scientific instruments. In addition, the Ministry has entered into long-term contracts for raw materials, including copper, lead, zinc, aluminium and timber, which amount to hundreds of millions of pounds a year. Part of this money is being laid out in the Dominions, but, naturally, the larger part is being spent in the production of manufactured goods in this country. Some 15,000 firms are involved, 2,190 of which have been added to the list since the outbreak of war. Since the war, too, 20 new ordnance factories have been put in hand at a cost of 45,000,000*l.*, and 300 contractors' factories have been extended at the cost of 10,000,000*l.* The output of shells has been doubled and ten times as many are being made as during the comparable period in the last war. Gun production, too, has been increased eight times, and during December the steel production was the highest ever achieved in one month. In 1914-1918, the total construction of transport vehicles from the United Kingdom was about 40,000. This time, in the first year, it will exceed 100,000 vehicles. Summing up, it may be said that in every direction there has been a quickening of pace, and Mr. Burgin put the factor at between three and five. This quickening has, of course, been necessitated by the higher rate at which material is being used. This effort is being assisted by our close relations with the French (whose Government have appointed a mission of their Ministry of Munitions to work in London), and with the Dominions and India.

The organisation of this vitally important branch of the national effort is more efficient than it was twenty years ago and, in so far as that is so, we have not committed the sin of failing to learn from our mistakes. At the same time, it must be admitted that this impressive machine has been subjected to neither overload nor overspeed tests, and that until it has done so it would be unwise to be too complacent about its performance. At present, the input is large and the output negligible. Before passing considered judgment, it would, therefore, be as well to wait until these conditions are reversed, as conceivably they may be in the near or more distant future. A word of warning is also, perhaps, necessary on the financial structure of the organisation, for it is on the stability of that part of the national machine that ultimate success must largely depend. Very large sums of money are being spent, if not poured out, and if this expenditure is shown to be necessary, the bill will be willingly met. If they are not, however, necessary the reverse will be the case and any form of waste will, we hope, be speedily followed by condign punishment. It is only fair to say that the Government realise this and that an elaborate system for investigating costs and checking profiteering has been set up. The determination to get full value for every pound spent will require unceasing vigilance, a vigilance which, we hope that officials of the Ministry will realise, it is their first duty to exert.

---

THE UNITED STATES OIL INDUSTRY.—The average daily production of crude oil in the United States totalled 3,865,750 barrels during the week ending December 16, 1939.

## NOTES.

### ADVISORY COMMITTEE ON TECHNICAL DEVELOPMENT.

JUST before Christmas, the important announcement was made that the Minister of Supply (the Rt. Hon. Leslie Burgin, M.P.) had set up an Advisory Council on Scientific Research and Technical Development, to assist him on scientific and technical problems. The new Advisory Council is highly representative, and comprises many names which will be familiar to readers of ENGINEERING. Lord Cadman is the chairman, and the members include Dr. E. V. Appleton, secretary, Department of Scientific and Industrial Research; Major-General E. M. C. Clarke, Director of Artillery (Military Adviser), Ministry of Supply; Major-General A. E. Davidson, Controller of Mechanisation Department (Military Adviser), Ministry of Supply; Dr. H. J. Gough, Director of Scientific Research, Ministry of Supply; Dr. H. L. Guy, chief engineer, Mechanical Engineering Department, Metropolitan-Vickers Electrical Company, Limited; Sir Harold Hartley, vice-president and Director of Research, London Midland and Scottish Railway; Professor R. S. Hutton, professor of metallurgy, University of Cambridge; Sir Frank Smith, Director of Instrument Production, Ministry of Supply; Professor R. V. Southwell, Professor of Engineering, University of Oxford; Professor G. I. Taylor, Yarrow, Research Professor of the Royal Society (Engineering); and Sir Henry Tizard, chairman, Aeronautical Research Committee. It will be recalled that the Ministry of Supply, through its Directorate of Scientific Research, controls a large volume of scientific and technical work with direct application to military needs. The object of the new Council will be to ensure that this work is conducted with due regard to recent advances in scientific knowledge. It will also initiate new proposals for research and technical development, and make recommendations regarding the most effective use of scientific personnel.

### THE COST OF PUBLIC CLEANSING SERVICES.

As might be expected, the cost of the services which are broadly grouped under the heading of "public cleansing"—a term which includes also the collection and disposal of refuse—is continuing to rise; and although the latest annual return published by the Ministry of Health relates only to the year ended March 31, 1938, and therefore excludes expenditure incurred in connection with war preparations, the total figure of 11,600,000*l.* shows an increase of 300,000*l.* over that for the preceding twelve months. As the introductory statement indicates, the figures are not strictly comparable, as the composition of the areas in which accurate records of weight were kept is not exactly the same in both cases; but the differences are not so great as seriously to affect the general trend as it appears from the statistics collected. Those relating to refuse collection were obtained from 395 local authorities in England and Wales, and the returns relating to street cleansing, from 391 authorities. Accurate records of the weight of refuse were kept in 84 areas outside London, and show that the average cost of collection and disposal was 16*s.* 1*d.* per ton for a total weight of approximately 2,046,000 tons, or 14·5 cwt. per 1,000 persons per day. The comparable figures for London were 20*s.* 10*d.*, 1,165,000 tons, and 16·1 cwt., respectively; and, for all of the 112 areas in which accurate weight records were kept, 17*s.* 10*d.*, 3,211,000 tons, and 15·1 cwt., respectively. The corresponding figures for the country as a whole in 1936-37 were 17*s.* 1*d.*, 3,411,000 tons, and 15·2 cwt.

### CHOICE OF LOW-VOLTAGE SWITCHGEAR.

The announcement that the Institution of Electrical Engineers is to resume the holding of ordinary meetings in London on Thursday, January 25, provided war conditions permit, will be generally welcomed by members. This welcome will be the more hearty in that the subject to be dealt with at the first meeting is to be fire-fighting equipment for electrical installations, and in that the whole of the time will be available for discussion. The proceedings will also be enlivened by the exhibition of a coloured film. In this connection, it may be well to record that one electrical body, the Association of Supervisory Electrical Engineers, has not allowed the war to interfere with its usual proceedings, and that on Tuesday, December 19, it held a meeting at which the important subject of the selection of low voltage switchgear was dealt with by Mr. R. T. Lythall. The British standard specification for high voltage switchgear, said the author, imposed a limit of 44,000 r.m.s. amperes for the breaking current, and there was no reason why this figure should be exceeded in the similar specification, which was being prepared for low voltage switchgear. Some purchasers called for switchgear of such high values as 100,000 kVA, which, at 400 volts, meant a current of 140,000 amperes, or three times the limit for high voltage gear. He suggested that a limit of 30,000 kVA at 400 volts should be applied in the specification. Having agreed on a limiting value of short-circuit, this must not be exceeded on the low voltage system, and the possible fault currents must be calculated. Mr. Lythall suggested a limit of 2,000 kVA for the transformer capacity where it was some distance from its connected switchgear, or 1,500 kVA where they were close together. If these sizes were insufficient the 'bus bars must be sectionalised with means of ensuring that the two sections could not be coupled together. The use of ring main distribution was also advocated.

### SPEEDIER RELEASE OF RAILWAY WAGONS.

The Minister of Transport has recently made the Railways (Demurrage Charges) Order, 1939, under the Defence Regulations, 1939. This authorises the railway companies, on and from December 15, 1939, to increase their demurrage charges for railway wagons, containers and sheets, and to reduce the "free time." Broadly speaking, the effect will be to reduce to 24 hours the "free time" allowed for loading and unloading, and to double the demurrage charges payable for detention beyond that period. The Order provides that Sundays, Bank Holidays and the period from 12 noon to midnight on Saturdays, shall not be included in the "free time," and that, when the "free time" begins after 12 noon on any day, the rest of the day shall not be included. Until March 31, 1940, registered coal merchants will be allowed 48 hours instead of 24 hours for unloading wagons. By that time they will be expected to have made such arrangements as will enable them to comply with the general requirements that wagons should be released after twenty-four hours. The Order provides that the charges and free periods set out in the schedule shall not apply to wagons used for the conveyance of coal, coke or patent fuel, where the operation of such wagons is regulated under a system of control agreed between the railway companies and the interests concerned and approved by the Minister of Transport. The Minister has given an assurance that the Order will be administered with due regard to any genuine difficulties which traders and agriculturalists may have in giving strict compliance, provided that they can show that, by the institution of a proper control of their forwarding arrangements, and, where practicable and necessary, the re-organisation of their unloading and storage arrangements, they have taken all reasonable steps to adjust themselves to the needs of the situation.

---

THE INSTITUTE OF FUEL.—The Secretary of the Institute of Fuel has asked us to repeat that, as recorded on page 358, *ante*, the offices of the Institute are at 30, Bramham-gardens, London, S.W.5. All communications should be sent to that address as the Institute has given up its Victoria-street offices.

NICKEL-MOLYBDENUM STEELS IN OIL PUMPING.—The manufacture and properties of steels intended for "sucker rods" in oil wells in the United States is described in an article which appeared in a recent issue of the journal *Steel*. It is stated that for arduous conditions of pumping, with loads up to 35,000 lb. per square inch, and in circumstances involving mild sulphide or salt-water attack, a steel of the following percentage composition: Carbon, 0·2; nickel, 1·8; and molybdenum, 0·3, has been found to give satisfactory service. For similar loads under more severely corrosive conditions, a steel containing 0·13 per cent. of carbon; 3·5 per cent. of nickel; and 0·3 per cent. of molybdenum is considered to give better results.

# THE ENGINEERING OUTLOOK.

## I. ECONOMIC RETROSPECT FOR 1939 AND OUTLOOK FOR 1940.

IN this series, last year, a continued decline in activity in the engineering industry on civil and export account was anticipated for 1939, in the absence of any marked improvement in the international situation. It was expected, however, that the intensified armament demand would more than compensate for this decline, in most branches of the industry. In point of fact, up to the outbreak of war, activity in the engineering industry increased much more rapidly than had been expected, and by the middle of the year it was running only slightly below the peak level achieved in the second quarter of 1937. Exports held up better than had been expected in the light of certain rather disquieting features of the situation, which had become apparent towards the end of 1938. Moreover, throughout the early part of 1939 there was an almost continuous stepping up of armament requirements owing to the progressive deterioration in international relations.

The steady growth in the dependence of the industry on armament orders greatly facilitated the change-over from peace to war conditions in September, though this does not imply that the transition was a particularly easy one for some sections. The motor industry, for example, has been seriously hit by the necessity for petrol rationing, and the prospective increase in the horse-power tax from January 1, 1940; while many branches of engineering which have an important export trade have been affected by the restrictions imposed in order to prevent goods from finding their way into the hands of the enemy, and to conserve supplies of vital commodities. These considerations, of course, have affected engineering less than many other branches of industry. Germany being a large exporter of machinery, comparatively few engineering products were subjected to export control. In the long run, in fact, there is little doubt that many sections of the industry are likely to benefit from the elimination of German subsidised competition, following the British decision to treat German exports as contraband.

Even the establishment of the Ministry of Supply, in June, probably had little immediate effect on the industry, as the compulsory powers given to the Minister were held in reserve, to be used only if the voluntary system, hitherto in force, should prove inadequate. In effect, the Ministry took over the responsibility for the supply of munitions and equipment previously resting on the War Office, and it was estimated that, of the total gross expenditure on the Defence Services (based on the 1939-40 Estimates, before making allowance for supplementary estimate), the Ministry of Supply would be responsible for some 100*l.* millions. Actually this under-estimated the importance of the Ministry in relation to the other Service Ministries, since a considerable part of the estimated expenditure of the latter represents pay of the Forces. An approximate analysis of the Estimates indicates that expenditure on warlike stores, buildings and tools by the Ministry of Supply was about 80·6*l.* millions, and that by other Service Ministries (including A.R.P. expenditure), about 333·2*l.* millions.

Although these figures do not represent entirely expenditure on engineering products, they do give some indication of the high degree of dependence of the industry on armament orders, even before the outbreak of war. In 1935, the latest year for which detailed statistics are available, the gross output of the engineering industry was some 440*l.* millions, and it has been estimated that direct armament expenditure on engineering supplies in 1939-40 would have amounted to 235*l.* millions, omitting supplementary estimates and the very considerable increase which must have been brought about by the outbreak of war. Even allowing for a substantial rise in civil output, therefore, armament orders must have accounted for some 30 per cent. of the total in the early part of 1939.

Estimates of direct armament expenditure on engineering supplies can only be approximate, but a detailed examination of the Service Estimates suggest that it increased from 30*l.* millions in 1935-36 to 60*l.* millions in 1936-37, 104*l.* millions in 1937-38 and 154*l.* millions in 1938-39. It is evident that this increase has been largely responsible for the rise in activity of the engineering and shipbuilding industries as a whole, shown in Table I, herewith. In the past, it has been possible to show these figures up to the third quarter of the year, but owing to the outbreak of war, none have been published for the third quarter of 1939. Reading these figures in conjunction with those for direct armament orders, given above, it is clear that civil demand must have reached a peak about the second quarter of 1937. There was then a fairly sharp decline until the latter part of 1938, which was more than sufficient to offset the increased armament activity. This decline appears to have slowed down somewhat in the early part of 1939, though the rise in the index of production, from 129·5 in the fourth quarter of 1938 to 136·7 in the second quarter of 1939, was probably due entirely to increased armament activity, and was not sufficient to indicate that the decline in civil activity had been arrested.

TABLE I.—*Indices of Production.*

| Year. | Engineering and Shipbuilding. | Iron and Steel Group. |
|---|---|---|
| | (1924 = 100.) | (1924 = 100.) |
| 1931— | | |
| 1st Qr. .. .. | 102·5 | 68·0 |
| 2nd ,, .. | 98·7 | 62·9 |
| 3rd ,, .. | 91·3 | 61·0 |
| 4th ,, .. | 89·1 | 71·6 |
| 1932— | | |
| 1st Qr. .. | 90·7 | 70·4 |
| 2nd ,, .. | 90·4 | 66·6 |
| 3rd ,, .. | 84·2 | 61·5 |
| 4th ,, .. | 88·2 | 66·2 |
| 1933— | | |
| 1st Qr. .. | 93·0 | 72·3 |
| 2nd ,, .. | 97·0 | 78·5 |
| 3rd ,, .. | 93·5 | 84·2 |
| 4th ,, .. | 100·4 | 93·7 |
| | (1930 = 100.) | (1930 = 100.) |
| 1934— | | |
| 1st Qr. .. | 88·7 108·1 | 104·7 |
| 2nd ,, .. | 92·3 111·8 | 117·6 104·3 |
| 3rd ,, .. | 92·5 113·1 | 110·6 98·2 |
| 4th ,, .. | 102·4 125·3 | 116·4 103·4 |
| 1935— | | |
| 1st Qr. .. | 105·6 129·2 | 118·1 108·1 |
| 2nd ,, .. | 103·5 126·9 | 123·2 109·5 |
| 3rd ,, .. | 102·2 125·5 | 124·1 110·3 |
| 4th ,, .. | 108·0 | 133·3 |
| 1936— | | |
| 1st Qr. .. | 116·4 | 146·2 |
| 2nd ,, .. | 122·5 | 149·5 |
| 3rd ,, .. | 121·7 | 149·1 |
| 4th ,, .. | 132·4 | 155·6 |
| 1937— | | |
| 1st Qr. .. | 136·4 | 158·1 |
| 2nd ,, .. | 138·2 | 165·6 |
| 3rd ,, .. | 134·9 | 165·5 |
| 4th ,, .. | 135·3 | 177·3 |
| 1938— | | |
| 1st Qr. .. | 132·7 | 168·4 |
| 2nd ,, .. | 128·8 | 131·6 |
| 3rd ,, .. | 124·6 | 106·4 |
| 4th ,, .. | 129·5 | 119·8 |
| 1939— | | |
| 1st Qr. .. | 133·2 | 149·1 |
| 2nd ,, .. | 136·7 | 176·5 |

Table I brings out the fact that, over the last few years, the engineering industry has shown much greater stability than the iron and steel industry. The index of production for the latter, after reaching 167·3 in the fourth quarter of 1937, declined steeply to 106·4 in the third quarter of 1938, but by the second quarter of 1939 it had recovered to 176·5. The figures for production and trade, shown in Table II, opposite, are available only up to August, 1939, but are sufficient to show the very rapid improvement which took place. The average monthly output of steel in 1938 was only 866,200 tons, but for the first eight months of 1939 this figure had increased to 1,088,600 tons. By the middle of the year production was running at about 1,150,000 tons per month. The average monthly production in 1939 was thus slightly higher than the previous record average for 1937. The engineering industry is primarily interested in the steel industry as the producer of one of its principal raw materials, and from this point of view it is satisfactory that, although production is maintaining a higher level than in 1937, prices have been fixed by the Iron and Steel Control well below the maximum prices ruling in that year.

Further evidence of the revival of engineering activity is provided by the employment figures shown in Table III, opposite. At July, 1939, the number unemployed was 65,492, the lowest figure recorded in the last ten years. The number insured, on the other hand, rose still further from 1,372,040 at July, 1938, to 1,472,520 at July, 1939, with the result that the number employed reached the record figure of 1,407,028.

British trade figures are available in detail only for the first eight months of 1938. During this period, retained imports of machinery amounted to 86,425 tons, approximately the same as for the corresponding period of the previous year. By value, however, retained imports rose from 14,284,000*l.* to 16,620,000*l.* Since the outbreak of war, import figures have been available by value only, but the rate of importation appears to have declined slightly since the earlier part of the year. Average monthly imports in the three months September to November were 1,782,000*l.*, compared with an average of 2,080,000*l.* in January to August, making total retained imports for January to November 21,965,594*l.*, compared with 19,405,192*l.* in the previous year.

In the first eight months of 1939, British exports of machinery amounted to 278,977 tons, valued at 36,070,174*l.*, compared with 312,426 tons, valued at 38,452,791*l.*, in the corresponding period of the previous year. This fall was probably due in part to the sharp rise in average value per ton which has been taking place in recent years, and which has frequently been mentioned in this series. The rise continued in 1939, but was much less pronounced, than in previous years. Since the outbreak of war, exports of machinery have averaged 2,541,000*l.* per month, compared with an average of 4,509,000*l.* in the first eight months of the year. In November, however, there were signs of recovery, exports in that month totalling 3,296,700*l.* In the first eight months of 1939 the British Empire took 57·5 per cent. of total exports of machinery, against 59·5 per cent. in the previous year. The cutting off of German exports should provide an opportunity for British manufacturers to increase trade with non-Empire countries, particularly South America. On the other hand, difficulty may be experienced in trading with Russia and the Scandinavian countries, which took 11·3 per cent. of total exports in the first eight months of 1939. German exports of machinery, including ships, vehicles, electrical machinery, and apparatus, and musical instruments, amounted in 1938 to some RM. 1,500 million, of which about 15 per cent. went to North and South America and 20 per cent. to other overseas countries.

The task of securing as great a proportion as possible of these exports is one which requires to be tackled vigorously by the British engineering industry and the Government. The importance of expanding exports in order to assist in paying for the war does not need stressing, but it would seem that, up to the present, the Government has devoted too little attention to this aspect of economic warfare. It is to be hoped, however, that recent criticism, both in Parliament and in the Press, may result in stronger action being taken on this question.

For the duration of the war, most engineering firms are likely to be working under considerable pressure, and those sections of the industry which are not normally concerned with direct armament production, and which do not have a very important export trade, are likely to be drawn into armament work, probably mainly as sub-contractors. In this connection, there has been, recently, a number of complaints that the resources of small firms are not being fully utilised. Some firms, it is asserted, have failed entirely to get armament orders, while others have received them as sub-contractors at second or third hand. In the latter case, the orders are often very irregular and do not allow the firms in question to keep their staffs fully employed and so to put forth their maximum effort. These complaints refer in many cases to firms which are considered capable of undertaking armament work and it would seem that, in the aggregate, such firms represent a considerable reservoir of supply which has not yet been tapped. In addition, many firms are not yet equipped for armament production. Here the complaint is frequently made that no reply is received to offers made to the Ministry of

Supply, and no attempt is made to investigate the plants and facilities available.

In many branches of engineering, the limiting factor as regards expansion of output is, undoubtedly the supply of labour. In the engineering trades, this question is being dealt with largely by direct negotiations between the employers and the trade unions, since in both cases representative organisations exist which are more or less continuously in touch on questions of wages. In cases where the employers and unions have no well-developed methods for the discussion of industrial requirements, however, such questions are to be considered by the Joint Advisory Council, which held its first meeting on November 1. This organisation, the scope of which is purely advisory, is composed of 15 members of the British Employers' Confederation and the same number of members of the T.U.C. General Council. Apart from a number of minor problems arising from the war, for example, the direct and indirect influence of the black-out on industrial efficiency, the Advisory Council will consider general questions of wages and the relation of wages and the cost of living. In particular, the Council is co-operating with the principal unions concerned—the Amalgamated Engineering Union, the Confederation of Shipbuilding and Engineering Unions and the National Union of Foundry Workers—in setting up area advisory committees in the civil-defence areas, where regional directors of supplies have been appointed by the Minister of Supply. These committees are to consist of representatives of the local employers and unions, and, once the machinery is in operation it is proposed to hold an inquiry to see whether similar committees might be set up for the Air Ministry.

The question of the expansion of labour supply, and the correlated problem of dilution, of course, became a major problem in many branches of the industry, and particularly in aircraft manufacture, some time before the outbreak of war. In June, 1939, the annual conference of the Amalgamated Engineering Union decided that dilution should be opposed until all available skilled engineering workers were in full-time employment. While the fear of dilution on the part of the workers, and the probable subsequent ill effects as regards unemployment among skilled men, once the immediate pressure is removed, must command sympathy, this decision did little to solve the problem since already, by June, it could be said that all skilled men were in employment in many parts of the country. Moreover, taking the country as a whole, the employment figures shown in Table III indicate that unemployment among skilled men must have been extremely low. However, the unions agreed to meet the Ministry of Supply and the employers with a view to ascertaining the extent of the proposed expansion of the industry: it had been pointed out by the General Secretary that it was predicted that 1,000,000 more men would be required in the industry in the near future.

In August, the proposals put forward by the Engineering Employers' Federation were considered by the National Committee of the A.E.U. Briefly, these proposals were that, where insufficient skilled labour was available, semi-skilled men should be allowed to work on the same basis as skilled men and to operate machines which are normally operated by skilled men only. Applications to relax practices and customs were to be dealt with by local committees, comprising representatives of employers and employees. It was proposed to give a guarantee that, as skilled men became available, ordinary practices should be resumed. On the outbreak of war, the immediate question became even more acute, since it was obvious that the labour supply would have to be increased much beyond what had previously been expected, while at the same time the point at which a decline in employment was likely to occur was considerably deferred. On September 1, it was announced that the A.E.U. were prepared to agree to a modified form of dilution in view of the national emergency. The details of operation of the scheme will be handled by the regional committees, referred to above.

Another question which has been much to the fore in all industries since the outbreak of war, in view of the rise of approximately 12½ per cent. which has occurred in the official cost of living index, is that of wages. In the engineering industry this question was already a live issue before the outbreak of war. After their previous application had been turned down in December, 1938, the Engineering Joint Trades Union accepted an increase of 2*s.* a week in the national bonus to all adult workmen as from June 5, 1939. Shortly afterwards, however, the A.E.U. made it clear that they proposed to present a new application in six months' time, possibly for an increase of as much as 10*s.* per week on the basic rate. In normal circumstances, in accordance with the agreement between the employers and the unions, neither side could raise the question again within six months of the increase; but, in view of the special circumstances created by the war, an informal meeting between the A.E.U. and the Engineering and Allied Employers' National Federation was held at the beginning of November.

No conclusion appears to have been reached as yet, and although an increase in the cost of living would appear, at first sight, a convincing reason for an increase in wages—the relation has been recognised as automatic in several industries—it is doubtful whether the principle can be admitted in time of war. The whole subject has recently received a great deal of attention in the daily Press and the view has been expressed that, if this principle is, in fact, applied, the workers themselves are likely to be no better off in the long run. It is pointed out that the initial rise in the cost of living may be occasioned by increased insurance and freight charges and the inevitable dislocation of normal business. An increase in prices due to such causes is not necessarily cumulative and prices may tend to settle down at a level, say, 10 per cent. to 15 per cent. above the pre-war level, particularly if measures for price control and the prevention of profiteering are rigorously applied. If, on the other hand, this initial increase in the cost of living is followed by compensatory increases in wages, as has already been the case in several industries, a further rise in prices is practically inevitable. The process then becomes continuous, but, since the increased production of armaments must result in a decline in the production of goods for consumption, the rise in prices must, eventually, outstrip any increase in wages. If, however, wage earners are to forgo an increase in wages, they must be convinced that the rise in prices has been occasioned by uncontrollable factors and not by attempts of one section of the community to profiteer at the expense of the remainder. At the present time, there appears to be a tendency, in several cases, to relax the control of prices instituted on the outbreak of war. Such action can only tend to strengthen the movement for higher wages.

Another important aspect of the wage question is one which has frequently been stressed in this series in previous years, namely, the effect on export trade. In war, as previously mentioned, export trade is even more vital to this country than in peace, and in this connection the depreciation which has already taken place in sterling has conferred an advantage on British manufacturers. It would be unfortunate if this advantage were to be thrown away on account of unjustified wage increases. It must not be thought that, because German exports are cut off from several markets, the latter can be automatically won by British manufacturers. The United States, in past years, has suffered to a considerable extent from subsidised German competition and United States manufacturers are likely to make every effort to regain lost markets, particularly in South America. They have the considerable advantage of being untrammelled by the controls and restrictions which to, some extent, are inevitable in a belligerent country.

TABLE II.—*United Kingdom Steel Consumption.*
(Monthly Average: Tons.)

| Year. | Production.* | Imports.† | Exports.† | Apparent Consumption. |
|---|---|---|---|---|
| 1930 .. | 610,500 | 191,600 | 193,800 | 609,300 |
| 1931 .. | 433,500 | 193,800 | 123,400 | 503,900 |
| 1932 .. | 438,400 | 112,400 | 126,900 | 433,900 |
| 1933 .. | 585,300 | 66,000 | 126,800 | 522,500 |
| 1934 .. | 737,500 | 96,500 | 145,200 | 688,800 |
| 1935 .. | 821,600 | 79,800 | 149,300 .. | 752,100 |
| 1936 .. | 982,000 | 90,800 | 143,100 | 929,800 |
| 1937 .. | 1,080,300 | 98,500 | 167,500 | 1,011,300 |
| 1938 .. | 866,200 | 67,800 | 118,900 | 815,100 |
| 1939 .. (Jan.-Aug.) | 1,088,600 | 109,600 | 113,600 | 1,084,600 |

* Crude steel.
† Steel and steel products, so far as these can be separated from those of iron.

TABLE III.—*Employment in British Engineering Industry.*

| Year. | Number Insured. | Number Unemployed. | Number Employed. |
|---|---|---|---|
| July, 1929 .. | 1,100,770 | 89,650 | 1,011,120 |
| ,, 1930 .. | 1,116,970 | 177,181 | 939,789 |
| ,, 1931 .. | 1,106,600 | 296,039 | 810,561 |
| ,, 1932 .. | 1,079,320 | 304,656 | 774,664 |
| ,, 1933 .. | 1,057,320 | 239,588 | 817,732 |
| ,, 1934 .. | 1,068,900 | 145,513 | 923,387 |
| ,, 1935 .. | 1,092,070 | 128,514 | 963,556 |
| ,, 1936 .. | 1,174,980 | 86,913 | 1,088,067 |
| ,, 1937 .. | 1,297,320 | 66,607 | 1,230,713 |
| ,, 1938 .. | 1,372,040 | 108,905 | 1,263,135 |
| ,, 1939 .. | 1,472,520 | 65,492 | 1,407,028 |

TABLE IV.—*United Kingdom Retained Imports of Machinery.*

| Year. | Volume. Tons. | Declared Value (£). | Value per Ton (£). |
|---|---|---|---|
| | | £ | £ |
| 1913 .. .. | 82,769 | 5,960,866 | 72·0 |
| 1929 .. .. | 107,874 | 17,522,792 | 162·4 |
| 1930 .. .. | 101,782 | 16,363,933 | 160·8 |
| 1931 .. .. | 87,826 | 14,135,086 | 160·9 |
| 1932 .. .. | 51,997 | 9,529,649 | 183·3 |
| 1933 .. .. | 41,144 | 7,846,771 | 190·7 |
| 1934 .. .. | 60,957 | 10,464,752 | 171·7 |
| 1935 .. .. | 69,489 | 11,521,856 | 178·2 |
| 1936 .. .. | 100,767 | 16,181,546 | 160·8 |
| 1937 .. .. | 144,079 | 22,327,745 | 154·5 |
| 1938 .. .. | 121,247 | 20,891,237 | 172·3 |
| 1938 (Jan.-Aug.) .. | 86,062 | 14,284,287 | 166·0 |
| 1939 (Jan.-Aug.) .. | 86,425 | 16,620,416 | 192·3 |

TABLE V.—*United Kingdom Exports of Machinery.*

| Year. | Volume. Tons. | Declared Value. | Value per Ton. |
|---|---|---|---|
| | | £ | £ |
| 1913 .. .. | 689,389 | 33,602,474 | 48·7 |
| 1929 .. .. | 562,263 | 54,350,821 | 96·6 |
| 1930 .. .. | 481,886 | 46,974,006 | 97·5 |
| 1931 .. .. | 329,264 | 33,011,639 | 100·3 |
| 1932 .. .. | 301,178 | 29,589,767 | 98·2 |
| 1933 .. .. | 276,312 | 27,143,286 | 98·2 |
| 1934 .. .. | 338,279 | 33,593,132 | 99·3 |
| 1935 .. .. | 383,833 | 39,352,247 | 102·5 |
| 1936 .. .. | 380,495 | 41,179,280 | 108·1 |
| 1937 .. .. | 438,377 | 49,776,062 | 113·2 |
| 1938 .. .. | 459,990 | 57,906,966 | 125·8 |
| 1938 (Jan.-Aug.) .. | 312,426 | 38,452,791 | 123·8 |
| 1939 (Jan.-Aug.) .. | 278,977 | 36,070,174 | 129·3 |

## SUDDEN DISCHARGE OF AIR FROM A PRESSURE VESSEL.

By S. J. DAVIES, D.Sc.

THE object of the experiments described here was to study the pressure conditions in a vessel following the sudden discharge of compressed air from the vessel. The apparatus used in the experiments is illustrated in Figs. 1, 2 and 3, page 18. It consists of a cylinder having an internal diameter of 4 in. and length of approximately 13 in. The cylinder is closed at one end, and is provided at the other end with an orifice 3⅛ in. diameter, in which is seated a valve having a masking ¾ in. long. For convenience, a cylinder used in previous experiments was employed. It will be noticed from Fig. 3 that the closed end contains a shallow recess, and that the valve embodies a cylindrical internal extension. These modifications did not in any way affect the validity of the experimental results. The external mechanism shown on the left in the figures is provided for holding the valve on its seating while the vessel is being charged with air to the required pressure, and for releasing the valve when desired. The valve is forced from its seating by the pressure of the air in the vessel and thus uncovers the orifice, the masking ensuring that the valve will have attained a high speed before the end of the masking clears the discharge orifice. This valve

mechanism, as will be seen in Fig. 3, comprises a spring-loaded lever which presses on the valve in the closed position and can be disengaged from the valve by striking an external tripping arm. The photographs reproduced in Figs. 1 and 2 show the valve in the closed and open positions, respectively.

The experiments consisted in charging the vessel with air at varying pressures, releasing the valve, and making observations of the minimum pressures reached in the vessel at the points marked A, B, C and D, in Fig. 3, and of the time intervals. These observations were made by means of the "Sunbury" cathode-ray oscillograph, made by Messrs. The Standard Telephone Company. To obtain the greatest possible accuracy, the calibrating unit of this instrument was used for measuring the minimum pressures reached in the vessel. For this purpose, provision was made to place the pressure elements and the calibrating unit, respectively, at the points A, B, C and D, and contacts were arranged so that the horizontal movement of the spot across the screen of the oscillograph commenced at the instant the end of the valve masking cleared the discharge orifice of the vessel.

As a first experiment, the vessel was charged with air to a series of initial pressures ranging from 0 lb. per square inch gauge to 60 lb. per square inch gauge, and the valve then released. In each case the value of the minimum pressure reached at the point A was measured by means of the calibrating unit of the indicator. The values thus obtained are recorded in the form of a curve of minimum pressure against initial pressure in Fig. 4, and it will be seen that, for all initial pressures above 1 lb. per square inch gauge, a depression was recorded in the vessel at A, following the discharge of the compressed air, the depression for the initial pressure of 60 lb. per square inch gauge reaching the value of 4·3 lb. per square inch.

In a second experiment, the vessel was charged with air to an initial pressure of 40 lb. per square inch gauge and, following the release of the valve and the discharge of the compressed air, the value of the depression reached at the points B, C and D (in addition to A) were measured. The values thus obtained are shown in Fig. 5 as ordinates on a base represented by the vessel itself, and it will be seen that the depression is greatest at the closed end of the vessel and least at the discharge orifice.

In order to obtain an indication of the time of occurrence of the maximum depression at points A, B, C and D in the second experiment, the calibrator diagram was photographed at each point with an applied static depression slightly less than the maximum depression occurring at the point concerned. It was found that at each point in the vessel the maximum depression was reached about 0·006 second after the commencement of opening of the orifice, but the accuracy of the time measurement was not sufficient to permit conclusions to be drawn concerning the exact instants of time at which the maximum depressions occur relative one to the other.

By repeating this experiment with atmospheric pressure applied to the calibrating unit, it was found that at all points the pressure in the vessel fell below atmospheric pressure about 0·0035 second after the commencement of opening of the orifice, and returned again to atmospheric pressure about 0·007 second after the commencement of valve opening.

The apparatus is designed to give a rapid opening of a large area of discharge orifice in the vessel. In order to obtain a measurement of the time taken to open the orifice fully in the second experiment, two time points were determined, one when the valve masking commences to clear the orifice and the other at the full opening of the orifice, *i.e.*, when the end of the valve masking had moved $\frac{13}{64}$ in. away from the orifice. This time interval was found to be 0·0019 second, showing that the orifice is already fully open before a depression is reached at any point in the vessel. By way of interest, it is indicated that the time for full opening at 20 lb. initial pressure was 0·0026 second, and at 60 lb. initial pressure 0·0015 second.

*Conclusions.*—The experiments show that the sudden discharge of compressed air from the vessel leaves a depression in the vessel even with the lowest initial pressures, and that this depression increases as the initial pressure increases, (experiment 1.) The distribution of pressure in the vessel shows that the depression is greatest at points most remote from the orifice, (experiment 2). The time intervals in which the depression occurs are short; the first fall below atmospheric pressure begins some 0·0035 second after the commencement of opening the orifice and the existence of the depression is not of long duration; certainly no longer than 0·0035 second.

## DISCHARGE OF AIR FROM A PRESSURE VESSEL.

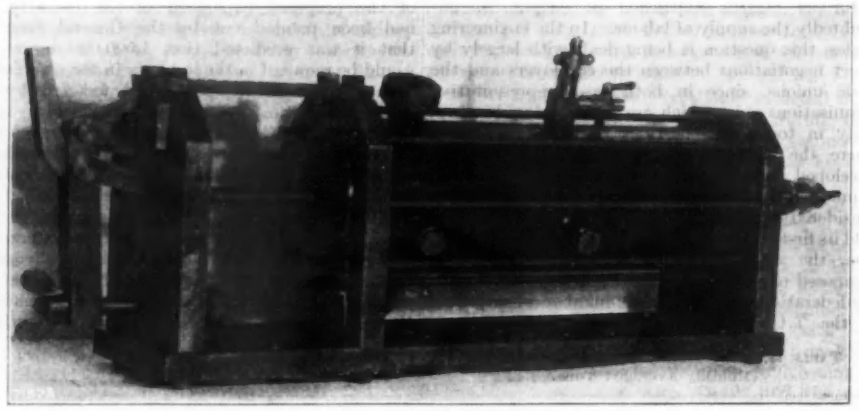


FIG. 1. CYLINDER WITH VALVE CLOSED.

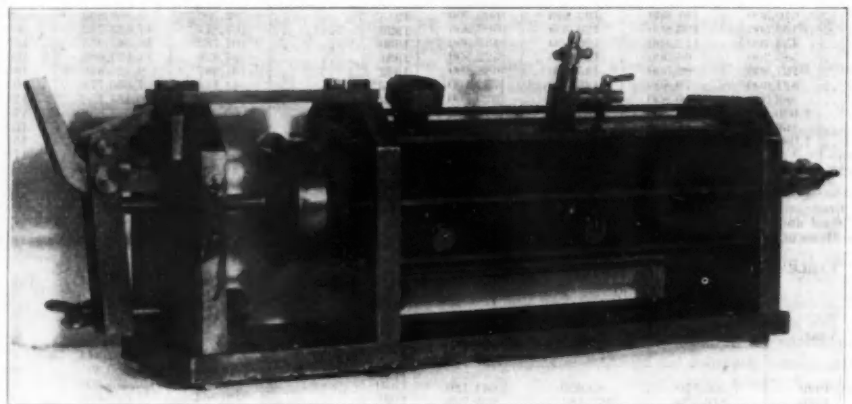
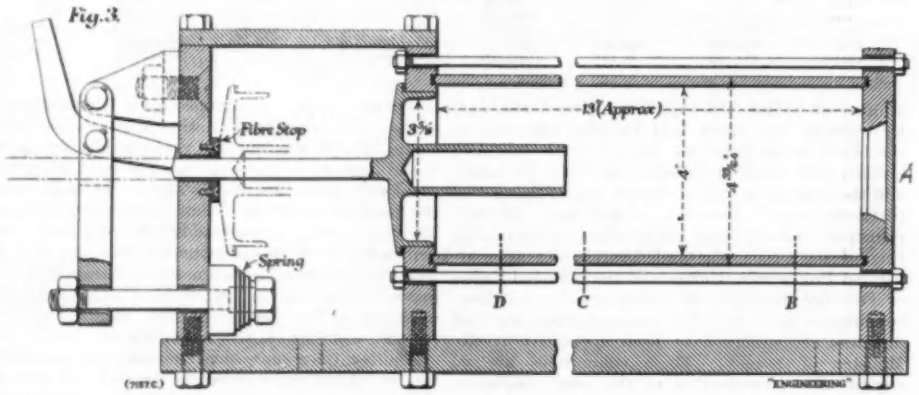
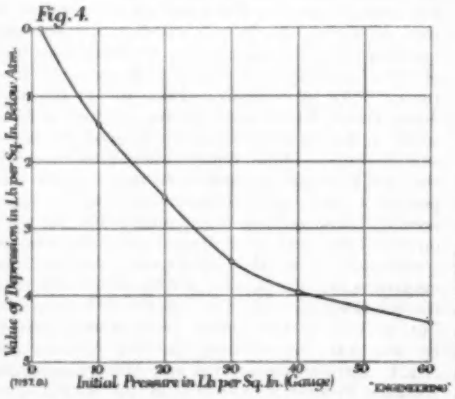
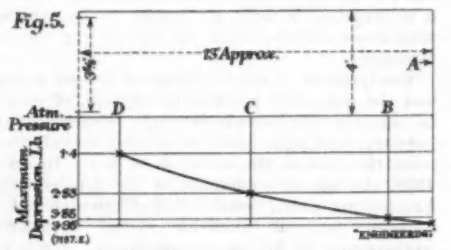


FIG. 2. CYLINDER WITH VALVE OPEN.



# LETTER TO THE EDITOR.

## THE KADENACY SYSTEM OF SCAVENGING.

TO THE EDITOR OF ENGINEERING.

SIR,—I have just seen Dr. Mucklow's letter in your issue of November 24, 1939, and would offer the following comments:—In my report of June 18 and 25, 1937, I described nine tests. Dr. Mucklow, in his article of August 18, 1939, gave his comments on three of these, ignoring the other tests, which gave evidence contrary to his views, including a test of an engine running without an exhaust pipe. In reply to this article I wrote at length, and several gentlemen did Dr. Mucklow the honour of offering contributions. I find Dr. Mucklow's short reply extremely unsatisfactory, both as regards contents and tone.

In his letter, Dr. Mucklow ignores (that is he neither accepts nor disputes) carefully presented evidence, claiming the need for brevity as excuse, and then takes up more than half his space in presenting a further experiment of the type against which, in my letter, I offered strong adverse criticism, directed mainly against the crudity of his methods. We are dealing here with a transient action occurring within a few thousandths of a second. His non-return valve, on account of its inertia, could not respond to the forces acting over the brief time interval available when no pipe was fitted. By fitting a pipe, the time was lengthened sufficiently to show a depression with this crude means, but, of course, without altering the origin of the depression, namely, the rapid initial outflow of the gas when the port is opened suddenly.

Dr. Mucklow complains that I did not describe my apparatus. I wrote that "I repeated this (Dr. Mucklow's) experiment, and added means for measuring the pressures . . . and made other improvements." I then went on to describe these improvements and why they were necessary. My apparatus obviously had the dimensions of Dr. Mucklow's but incorporated these improvements. Simply to hint in reply to my experimental data that my indicator was unreliable is mere sophistry.

The major difficulty seems to be that Dr. Mucklow considers all actions to conform to the laws of steady flow, and that he persists in ignoring the discontinuities consequent upon the very short intervals of time involved under engine conditions. (For example, at the moderate speed of 1,200 r.p.m., the whole exhausting and recharging of the cylinder of a two-stroke engine takes only 0·016 second.) Until, therefore, he approaches the experimental data of others with a suitably open mind, I have no intention of continuing this correspondence, and prefer to leave your readers to draw their own conclusions from the whole discussion since June, 1937.

I am, Sir,
Yours faithfully,
S. J. DAVIES.

University of London, King's College,
University of Bristol.
December, 1939.

[In connection with this correspondence, the article by Professor Davies on the sudden discharge of compressed air, appearing on page 17 of this issue, is of considerable interest.—Ed., E.]

## UNIVERSAL MILLING ATTACHMENT.

THE practice of increasing the utility of the horizontal-spindle milling machine by means of an attachment which enables milling, drilling, etc., to be done with a spindle adjustable to lie at any angle is becoming more common. One of the latest of such auxiliaries is the "All Angle" milling attachment manufactured by Messrs. Fray Machine Tool Company, Glendale, California, U.S.A., and distributed in Great Britain by Messrs. Broadway Engineering Company, Limited, Carlisle-road, Hendon, London, N.W.9. The attachment is arranged for clamping to the overarm of the milling machine, and is provided with a self-contained motor drive. The clamping arm is fitted with an adaptor machined to fit the particular diameter of overarm concerned and carries on one side a spigoted facing to which the spindle housing is clamped. As the axes of the overarm and of the spigoted facing are at right angles, the spindle has universal movement, and both the clamping arm and the housing facing are graduated to 360 deg. The spindle housing carries a heat-treated and ground quill in which the hardened and ground chrome-molybdenum steel six-splined spindle is mounted in three rows of radial thrust ball bearings.

The quill is driven from the motor through a pair of six-step Vee-belt pulleys, the axis of the motor spindle being parallel to that of the spindle. The driving pulley on the motor spindle is in a single piece, but the driven pulley on the tool spindle is in two parts, viz., a four-groove pulley with a separate two-groove pulley below it. This pulley is provided with internal speed-reducing gear of the planetary type. When the two parts are engaged, six tool spindle speeds are obtainable by changing the belt, the range being from 375 r.p.m. to 5,200 r.p.m. When they are disengaged and the belt is on either of the two bottom steps, the drive is through the planetary gear and speeds of 250 r.p.m. or 125 r.p.m. are obtainable. The very high speeds are intended for use when the attachment is required for grinding. The standard spindle nose being a No. 7 Brown and Sharpe collet, in which small tools of all rotating types may be held. The lower speeds are useful when such operations as end milling are being carried out, the recommended speeds for a 1-in. end mill, for example, being 325 r.p.m. for soft steel and 350 r.p.m. for cast iron. The motor, which is ¾-h.p. and the standard types are either for 220-volt, three-phase or 110-volt single-phase alternating current. It is carried on an aluminium alloy stool sliding on a bracket attached to the top of the tool spindle housing, belt tensioning being effected by moving the motor.

Control of the attachment is effected as regards stopping and starting by a three-position switch on top of the motor, giving forward and reverse motions, and "stop." The tool spindle may be fed either by a handwheel, having a micrometer dial graduated to 0·001 in.; or by a lever of the sensitive type. A clutch enables either feed to be used at will. A window in the housing shows a graduated scale on the quill, so that the rate of traverse may be watched. In addition, there is a depth stop graduated to read to 0·001 in. Positive locking gear is fitted to this stop, to the quill and to both setting movements of the spindle housing. It will be understood that the attachment need not be removed from the milling machine when that is engaged on its normal work, the attachment being then swung upwards out of the way until the tool spindle is horizontal. The dimensions are such that the attachment can be used with the tool spindle horizontal below the overarm when drilling or milling surfaces vertical to the machine table. The setting movements are readily carried out as the attachment is statically balanced.

## THE LATE MR. WILLIAM BARTON WORTHINGTON.

WE regret to record the death, at the advanced age of 85, of Mr. William Barton Worthington, formerly engineer-in-chief of the Midland Railway and President, in 1921, of the Institution of Civil Engineers. The son of Samuel Barton Worthington, M.Inst.C.E., engineer to the Lancaster and Carlisle Railway, who had been a pupil of John Locke, W. B. Worthington was born at Lancaster in 1854, and received his early education at Dr. Davis's private school in that town. Thence he proceeded to Owens College, Manchester, where he obtained the B.Sc. degree of London University. In 1873, he was articled to his father, under whom he was engaged on the construction of Carlisle station. Two years later he joined the engineering staff of Messrs. Blyth and Cunningham, of Edinburgh, for constructional work in connection with the Caledonian Railway, leaving their service in 1876 to take up an appointment as resident engineer for new works with the London and North Western Railway. His district was South Lancashire, where he supervised the widening of the Liverpool and Manchester line between Chat Moss and Manchester, and the building of Manchester Exchange station.

In 1883, Mr. Worthington was appointed as assistant to his father, who was then holding the position of engineer for the Northern Division of the London and North Western Railway, and three years later he succeeded his father in that office. He remained until 1890, when he transferred to the Lancashire and Yorkshire Railway as assistant engineer, becoming chief engineer in 1897. Eight years later, in 1905, he was appointed chief engineer of the Midland Railway, retaining that position until he retired in 1917. He was elected to the Institution of Civil Engineers, as an associate-member, as long ago as 1880, being transferred to the class of member in 1884. In 1907, he became a member of the Council of the Institution, serving as such until 1915, when he was elected vice-president. In 1917, he was elected president, but was unable to accept office on account of ill-health. He was re-elected vice-president in 1918, and in November, 1921, was elected a second time as president, on this occasion accepting the office. In 1923, the degree of Doctor of Science was conferred upon him by the University of Manchester. Mr. Worthington was also a member of the Institution of Mechanical Engineers, of which his brother, the late Mr. Edgar Worthington, was secretary for many years, and which he joined in 1897. His death took place on December 29, 1939.

## THE LATE MR. A. H. G. FOKKER.

PERSONALITY has played a greater part in aviation than in most other engineering developments, probably due to the fact that in the early days of heavier-than-air machines, the designer had perforce to act as his own test pilot. Many of the pioneer machines were, in fact, of such flimsy construction, and so unstable, that only the enthusiasm of their originator could ensure their trial in actual flight, and some of the best known names in the annals of aviation, such as that of Colonel Cody, stand out rather for the personal courage of their holders than for their ability as designers. At a somewhat later date, when the basic principles of flight were better understood, a much higher degree of designing ability became essential to success, and it is to this period that Fokker belonged. The earlier machines bearing his name, without displaying outstanding originality, were among the best available at the time, and the high respect accorded to the Fokker machines used by the Germans in the last war is perhaps the best tribute which could be paid to his ability.

Anthony Herman Gerard Fokker, who died in New York on December 23, was born in Java in 1890, his father being a Dutch planter resident in the island. The family returned to Holland when he was six. His interest in aviation was first aroused when he was about 18 years old by the reports on the work of the early pioneers, and he carried out numerous experiments on models with a view to finding means to improve lateral stability. After making some progress, these experiments were interrupted by a year's compulsory service in the Dutch army, after which he attended a course of aviation in Zalbach, Germany. Soon after this, he built his first aeroplane with the financial assistance of a fellow student, which, although it actually rose in the air, crashed on the second flight. After alterations, however, this machine enabled Fokker to learn to fly, and he was able to make a number of improvements to the design. Finally, he succeeded in obtaining his flying certificate at Mainz on the machine, and subsequently used it for a number of exhibition flights in Holland. He then flew the machine from Berlin to Doberitz, a distance of 730 km., and at this stage, attempted to interest the Dutch Government in his work. In this he failed, but not discouraged, built a second machine in which he was able to loop the loop, for the first time in Germany, and in which he gave exhibition flights up to the outbreak of war in 1914. Some time before this, he had been endeavouring to interest the governments of various countries in his design, and after discouraging experiences in Holland, Italy, Russia, and England, succeeded in 1913 in getting them taken up in Germany.

At the outbreak of war, he produced a single-seater fighter of great merit, which proved a thorn in the side of the Allies. It was in connection with this machine that an opportunity occurred for Fokker to utilise his inventive ability to the full. A French machine flown by Garros had been brought down behind the enemy lines fitted with a machine gun firing in the line of flight, the bullets being deflected from the propeller blades by metal plates. The German High Command asked Fokker whether he could improve on this idea, and although it is said that he had never seen a machine gun before, his famous interrupter gear, in which the gun was synchronised with the propeller, was evolved within three days. His later experiences in Germany during the war were hardly happy ones. There was apparently great resentment among German manufacturers that one of the most prominent positions in the industry should be held by an alien, and in spite of the fact that his monoplane had shown great superiority over the opposed allies designs, their influence was so far successful that Fokker's works were relegated to the production of training machines of German design. He was pressed to take out naturalisation papers, and when he refused and expressed a wish to return to Holland, every possible obstacle was put in his way. In spite of these discouragements, he was able to turn out a new machine, the Fokker D 7, which proved superior to any existing machine of German design. It was in connection with machines of this type that one of the most romantic episodes in Fokker's life occurred. It was a condition of the peace terms that all German aircraft should be destroyed, but Fokker succeeded in smuggling over 200 of his machines, motors, and accessories into Holland.

After the war, Fokker established a large factory in Holland, still in existence as the N.V. Nederlandsche Vliegtingenfabriek Fokker, of which he was managing director at the time of his death. He came to England in 1922, in connection with glider work, and in the same year he went to America and organised the Atlantic Aircraft Corporation. He also established a plant at Wheeling in co-operation with a group of industrialists. Later the Atlantic company was affiliated with General Motors, and Fokker became chief of their aviation department.

## LABOUR NOTES.

So many wage increases have been conceded and so many applications for increases are under consideration that the whole problem of the remuneration of labour is becoming sadly out of focus. With British labour costs at the present level no trades manufacturing for export can hope to function economically. Yet the powers that be—and others—never tire of urging them to develop their export trade. Access to neutral countries by German manufacturers is, for reasons which are not obscure, rather limited, but if there were no war, or if there were fewer world markets closed to them—and, of course, no two-way contraband control—their lower wage rates and longer working hours would constitute a serious problem for British manufacturers—a problem, moreover, which will last for a long time after the warfare ceases. Our representative Labour men do not appear to realise that, and, as in the case of the miners, are insisting on the co-relation of wage rates and the cost of living, without regard to either the immediate or the ultimate effect of the action. The ultimate effect must be to cripple our export trade after the war. The immediate effect is to send the cost of living index figure up to higher and higher levels.

---

According to the December issue of *The Ministry of Labour Gazette*, the wage changes reported in the first eleven months of 1939 are estimated to have resulted in a net increase of about 650,000*l.* a week in the rates of over 3,700,000 workpeople and in a net decrease of 14,000*l.* in those of 93,000 workpeople. These wage changes, assuming full time to be worked throughout, but leaving overtime and other additional payments out of account, add 33,000,000*l.* to the spending power of the wage earners. A still more significant fact in this connection is that the changes in rates of wages reported to have come into operation in November are estimated to have resulted in an increase of about 350,000*l.* in the weekly full-time wages of 1,947,000 workpeople and in a decrease of 300*l.* in those of 10,000 workpeople. On the showing of these figures, the total of the wage increases is growing from month to month, and is having its due effect on the cost of living figures. The principal groups of workpeople whose wages were increased in November included coal miners in all districts, workpeople employed in steel melting shops and rolling mills in various districts, pottery workers, soap and candle makers, workpeople employed in the manufacturing section of the cotton industry and in the woollen and worsted industry, hosiery makers, furniture trade operatives in various districts, workpeople employed by electrical contractors, dock workers, and workpeople employed in the wholesale mantle and costume trade.

---

*The Ministry of Labour Gazette* states that among insured persons between the ages of 16 and 64 the percentage unemployed in Great Britain and Northern Ireland at November 13 was 9·2, as compared with 9·3 at October 16 and 12·6 at November 14, 1938. For persons insured under the general scheme, the corresponding percentages were 9·5 at November 13, 9·6 at October 16, and 13·4 at November 14, 1938. For persons within the agricultural scheme, the percentages were 5·1, 4·0 and 5·7, respectively.

---

At November 13, there were registered as unemployed in Great Britain 1,213,345 persons who were out of a situation. This was 8,310 less than at October 16 and 242,323 less than at November 14, 1938. There were on the registers in Great Britain 135,233 persons who were on short time or otherwise temporarily suspended from work. This was 11,218 less than at October 16 and 170,263 less than at November 14, 1938. Of persons who normally seek a livelihood by means of jobs of short duration, there were on the registers in Great Britain 54,010. This was 8,522 less than at October 16 and 12,929 less than at November 14, 1938.

---

The total of 1,402,588 persons on the registers at November 13 included 1,204,499 applicants for benefit on allowances and 198,089 non-claimants. The latter figure showed a decrease of 17,987 as compared with October 16.

---

At December 1, the average level of retail prices of the commodities taken into account in the statistics compiled by the Ministry of Labour (including food, rent, clothing, fuel and light, and miscellaneous items) was approximately 73 per cent. above the level of July, 1914, as compared with 69 per cent. at November 1. The rise of 4 points (*i.e.*, from 169 to 173, the figure for July, 1914, being 100) is equivalent to about 2¼ per cent. For food alone, the index figure at December 1 was 57 per cent. above the level of July, 1914, showing a rise of 3 points or about 2 per cent. since November 1, when the figure was 54 per cent. above the level of July, 1914. The rise in the index figure for food was due mainly to increases in the prices of eggs, fish, bacon and cheese. Among items other than food the principal changes were increases in the prices of clothing, coal and gas.

---

The number of trade disputes involving stoppages of work, reported to the Ministry of Labour and National Service as beginning in November, was 79. In addition, 10 disputes which began before November were still in progress at the beginning of that month. The approximate number of workpeople involved in these 89 disputes, including workpeople thrown out of work at the establishments where the disputes occurred, was 43,000, and the aggregate duration of the disputes in November was about 132,000 working days. The aggregate duration of all disputes in progress during the first eleven months of 1939 was about 1,307,000 working days, and the total number of workpeople involved in these disputes was about 324,000.

---

A delegate conference of the Mineworkers' Federation of Great Britain, which was held in London on Friday last week, rejected the offer of the coal-owners to add 4*d.* a shift to the wages of men and 2*d.* a shift to the wages of youths—this would have made the war additions 1*s.* and 6*d.*, respectively—and decided to seek the authority of its district organisations to continue negotiations for "an advance in wages to operate from January 1, which shall at the minimum compensate for the increased cost of living." It was also resolved that "in the event of the negotiations being unsuccessful a further conference of the Federation be called to consider the action to be taken to enforce this demand." Although the resolution did not expressly call for a cost-of-living sliding scale adjustment of wages, it is understood that a sliding scale would be preferred to an advance of wages related only to the conditions of a particular time.

---

Explaining the effect of the resolution at the close of the conference, Mr. Lawther, the president of the Federation, said that the decisions of the district associations would be obtained as quickly as possible "in order that the executive may seek to get a cost-of-living formula adopted by the owners." "The conference was (he added) very emphatic against the general attitude taken up by the owners who can, we know, well afford, even in the worst economic districts, to pay the amount asked for in our formula. This would be approximately 1*s.* 4*d.* a shift." As most of the associations approved the resolution during the week-end, the Federation will probably have met the coal-owners again by the time this issue of ENGINEERING has gone to press.

---

The Minister of Shipping announced last week that the Government had decided to accept the offer, made on behalf of the shipowners, to share with them in equal proportions the cost of paying wages to all surpervising officers and men whose ships are torpedoed, mined, etc., for a period of one month, or until they reach this country, whichever should be the greater. The owners further offered to supplement during the second month the compensation payable to those injured. Where a man was in receipt of full disability allowance he would receive full wages.

---

The foregoing arrangements were reached after a deputation had been heard from the Shipping Federation, the War Risk Associations, the Mercantile Marine Service Association, the Officers (Merchant Navy) Federation, the Marine Engineers' Association, the Amalgamated Engineering Union, and the National Union of Seamen. They will be embodied in a notice to masters which will be published in the near future. These payments will take the place of ordinary shipwreck unemployment indemnity. It was agreed that the arrangements should become operative on December 1, 1939, and should apply to all merchant ships lost by enemy action on and after that date. The representatives of the officers' and men's societies expressed their appreciation of the owners' generous offer, and that the Government had seen their way to accept it. The arrangements, it was added, would be highly appreciated by all those serving in the Merchant Navy.

---

Commenting upon the inquiries which the Industrial Welfare Society is making regarding the effects on workers of war-time restrictions on lighting and transport, the writer of the editorial notes in *Man and Metal*, the journal of the Iron and Steel Trades Confederation, says that there is not much evidence of increased industrial accidents. "The black-out, however," he continues, "is causing some difficulty, although the additional care that such conditions instinctively call for is, no doubt, responsible for a lower accident rate than was generally expected. One of its results, however, which cannot be immediately seen, is the eye strain that must follow the continual peering for unexpected obstacles and feeling one's way about works' sidings in inky blackness. The results of all this may only become evident after a period of years, and there is no doubt that many workmen may, in future, be disabled by eye trouble for which no compensation can be claimed."

---

The greatest source of trouble will be, the writer believes, ventilation. "The difficulty of adjusting the needs of the lighting restrictions to the necessity of providing sufficient ventilation to enable men to carry on with their jobs is," he says, "in some cases well-nigh insuperable. In certain instances . . . the restrictions have been pushed to such a point . . . that departments have practically become sealed heat chambers. Many firms, on the other hand, have gone to considerable expense to overcome this, and will, in due course, reap the advantage. They will suffer less through absenteeism and loss of output."

---

The National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Railway Clerks' Association have appealed to the four main-line railway companies for further increases of wages. The National Union of Railwaymen and the Associated Society of Locomotive Engineers and Firemen are asking for an all-round increase of 10*s.* per week. The Railway Clerks' Association, whose members are paid on a different basis, are claiming an increase of 20*l.* a year. The railway companies have promised to give immediate consideration to the claims.

---

The following statement has been issued jointly by the British Federation of Master Printers, the Newspaper Society, and the Printing and Kindred Trades Federation:—Conferences are taking place between the British Federation of Master Printers, the Newspaper Society and the Printing and Kindred Trades Federation to consider certain proposals in relation to the Agreement on Emergency Conditions. Proposals are being submitted to the trade unions and the employers' organisations in regard to payment in the event of air-raid warnings, the working of short time, and the replacement and reinstatement of apprentices serving with the Forces, and decisions are likely to be reached early in January. Meantime, however, in order that effect may be given to it forthwith, the unions have approved in principle a recommendation that a paragraph be added to clause 3 of the Agreement on Emergency Conditions (Rearrangement of Hours) to the effect that working on Saturday afternoon is undesirable except where it is necessary to enable the working week to be completed in daylight during the months of December and January.

---

*Industrial and Labour Information* states that the measures introduced in Belgium by the Royal Order of September 2, 1939, in connection with the vocational retraining of workers in the coal-mining industry were supplemented by a Royal Order issued on November 24, 1939, which provides for further exceptional measures intended to secure the necessary supply of skilled labour for the industry. The new Order authorises the National Employment and Unemployment Office to allot a part of the credit granted for the payment of unemployment benefit and allowances to the purpose of subsidising employers in the coal industry who undertake to train Belgian workers employed underground as labourers for skilled work underground.

---

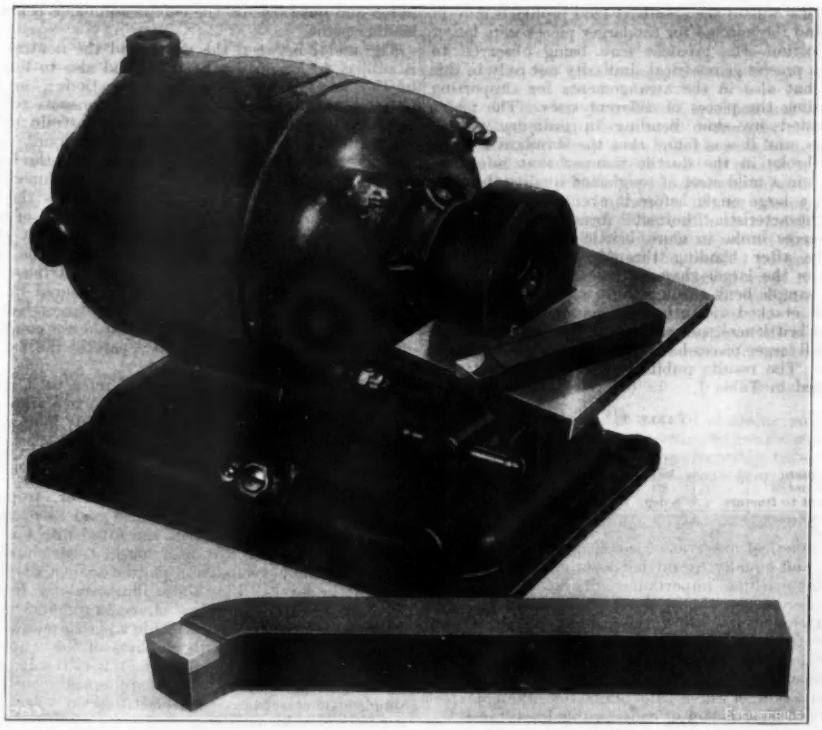
In order to obtain a subsidy, employers must undertake: (1) to pay to all unskilled workers undergoing training, from the beginning of the training, a wage at least equal to the minimum wage paid to skilled underground workers; (2) to hold an efficiency test at the end of each month for workers undergoing training and to reject all those whose aptitude proves to be insufficient; (3) to engage for unskilled work underground one wholly unemployed person from among those submitted by the National Employment and Unemployment Office for every worker selected for vocational training in accordance with the conditions specified in the Order.

---

In accordance with the Wages (War Adjustment) Agreement made between the National Federated Electrical Association and the Electrical Trades Union, on November 24, 1939, the parties have declared that as from the second pay-day in January, 1940, for the pay period covered by that pay-day, the cost of living (war) addition shall be 5*s.* 10*d.* per week and that such addition shall remain current up to and including the first pay-day in April, 1940. The addition declared replaces the payment of 3*s.* 6*d.* per week in accordance with the Interim (War Adjustment) Agreement of October 18, 1939.

# GRINDING MACHINE FOR CARBIDE-TIPPED TOOLS.

MESSRS. VAN DORN ELECTRIC TOOLS, SLOUGH.



## PORTABLE GRINDING AND LAPPING MACHINE FOR TUNGSTEN-CARBIDE TOOLS.

THE small portable grinding and lapping machine shown in the accompanying illustration has been designed by Messrs. Van Dorn Electric Tools, Slough, for the maintenance of cutting tools tipped with Ardoloy, or the different types of tungsten-carbide hard metals, and is marketed by Messrs. Alfred Herbert, Limited, Coventry. As will be evident, the machine is compact and of the bench type, these characteristics fitting it for use in shops where hard-metal tipped tools are employed, so that an operator can recondition the cutting edges without time being lost in transit to and from the tool room, production being thus not interfered with. The re-sharpening is done by a Norton diamond-impregnated cup wheel, 3 in. in diameter by $\frac{7}{8}$ in. wide by $\frac{1}{4}$ in. edge. The wheel is mounted directly on the motor spindle, the speed being 7,500 r.p.m., which gives the correct surface speed for the diameter and grain. The standard grain is 150, but the machine can be supplied with wheels of finer grain, viz., 220 or 320.

The motor is assembled on a substantial baseplate and special attention has been given to secure vibration-less running though holes are provided in the baseplate for holding-down bolts, if it is preferred to anchor the machine firmly. As the winding is of the universal type, either direct current or alternating current can be used. A choice of voltages is provided, the machine being available with windings for either 110 volts, 200/220 volts or 230/250 volts. Control is by a tumbler switch on the baseplate. As shown, a tool rest forms part of the standard machine, but this can be easily removed if desired. The tool rest is adjustable so that it can be set at the correct angle, viz., that coinciding with the clearance angle of the tool to be ground. This is important, since undue wear of the diamond wheel would result if the tool were not held flat against the wheel face. No coolant or cutting lubricant is required and the cutting surface of the wheel can be readily cleaned and restored to its original sharpness by dressing it lightly with a piece of pumice stone or with a fine and soft Crystolon stick.

---

RAINBOW BRIDGE, NIAGARA FALLS.—It is stated in a recent issue of *The Canadian Engineer* that work on the new international Rainbow Bridge at Niagara Falls is to begin during the present month. The Hon. T. B. McQuesten, minister of highways of the Province of Ontario is reported to have declared that the structure should be completed and ready for traffic by April, 1941.

## ELECTRIC WELDING AS AN INTEGRAL PART OF STRUCTURAL DESIGN.*

By PROFESSOR B. P. HAIGH, M.B.E., D.Sc.

WE are gathered this evening to honour the name and memory of Andrew Laing, a great engineer, whose life work affords an example to all who would serve by practical action rather than by precept. It is not recorded that Laing contributed to engineering science any outstanding discovery or invention; but as a practical engineer he kept closely in touch with scientific thought and recognised intuitively the developments on which sound progress could be based. Engineering in his hands became a fine art; and as an artist he lived for his art. The example of his life work turns our thoughts to practical developments and to their influence on future practice. I propose, therefore, to discuss electric welding and its probable influence on structural design and practice. The process is one that affords opportunities for engineer-artists to design more strongly, more tastefully, and more economically than ever before; and for trustworthy craftsmen to make and sell their products where others cannot.

The industrial and professional importance of electric welding lies in one point; the process affords a means of depositing and using a little sound metal in the right place rather than more elsewhere. In developing this theme I propose first to refer to certain principles in welding, and to quote data to show how reliably strong are the joints produced by current processes applied in different fields of structural practice. It will be shown that welded joints are not merely stronger than riveted, but stronger in such degrees as appear to justify important reductions in scantlings and, also, valuable changes in methods of structural design. All methods of welding comprise combinations of two distinct processes: (*a*) of heating, by charcoal, coke, water-gas, acetylene or electricity, to a temperature at which grains of "gamma" steel grow rapidly by crystallisation, and (*b*) of supplementing the relatively slow action of crystalline growth by the use of hammers, rollers, automatic or other presses, or by the use of "filler-rods" or "electrodes" to supply additional material to fill the gaps between the parts to be joined.

The oxy-acetylene process is subject to important difficulties when practised on a scale appropriate to structural work. Large volumes of metal in the plates or sections to be joined are slowly heated nearly to the melting point, although only the surfaces are actually melted. Radiation from the large incandescent areas renders the task fatiguing in the extreme, and the subsequent cooling of the large volumes tends often to soften the metal and exaggerate warping in the structure. The relatively slow rate of cooling eliminates at least one cause of brittle cracking, but tends to produce a coarse and brittle "gamma" structure in the deposit and adjacent metal; and the harmful influence of this coarse structure continues after the gamma grains, on cooling, change to ferrite and pearlite.

In electric welding, a technical difficulty occurs in striking and maintaining the arc to form a puddle of molten steel on the work; but when this first difficulty has been surmounted the process enters upon its normal regime. The heat of the arc melts and evaporates metal from the electrode, which delivers a stream of vapour and liquid that condenses upon and crystallises between the parts that are being joined. In condensing and cooling, this metal gives out its latent and sensible heat to the relatively cool work, which is thereby superficially heated to the melting point ready to receive more metal by condensation. The formation of a reliable weld demands fundamentally that metal shall be deposited only on surfaces that are already molten.

The thermal processes that occur in a welding arc are of considerable interest and may be compared with those in an evaporator and condenser—or even in a complete turbine plant, for the discharge of moist vapour from the electrode is so rapid that the force of reaction is appreciable, setting an upper limit to the size that can be operated by hand; larger sizes can be controlled only by machines provided with automatic feed mechanisms. Although the rate at which the vapour is boiled off the electrode depends on the current used, the more important rate at which it condenses and crystallises upon the work depends more directly on the rate at which heat is conducted away from the molten puddle. In the open arcs that are generally used in welding, the two rates are not necessarily the same. After freezing, the deposit contracts in volume continuously with fall of temperature, and may expand or contract, in different cases when changes of physical state occur at particular temperatures. In structural practice, these contractions result in warping and are a cause of difficulty.

The stresses induced by contraction during cooling tend to cause cracking. When the layer of cooling metal is relatively thin, so that the stress acts only in two directions near the surface, the tension is commonly relieved by plastic strain in the metal before it can reach values high enough to cause cracking; thus, plastic strain serves as a "safety valve" in the metal. The conditions are often more dangerous in thicker welds when the different parts cool at different rates, particularly in the later stages, when the outside is already cool and rigid while the inner part remains hotter and relatively liable to crack under the action of "triple" tensile stress. Two types of cracking can be distinguished in such case: (1) the outside may crack in an earlier stage of cooling if or when it contracts too rapidly, and (2) the inside may crack at a later stage if or when it continues to contract after the outside has hardened. Cracking in high-tensile steels is often attributed to the presence of martensite, but it should be borne in mind that the reduction of martensite involves further contraction at low temperature and, therefore, is liable to cause cracking of the second type. It is desirable that weld-deposits should be endowed with ductility in sufficient degree to act as a safeguard against the simpler types of stress; but even ductile deposits are liable to crack under the action of "triple" tensile stress. Slow rates of cooling are beneficial in this respect.

The use of covered electrodes originated in Sweden, but developed more rapidly in England than abroad as the demand for tough reliability was more insistent. Coverings operate beneficially in a number of ways: by keeping the electrode in shape to form a suitably short arc; by surrounding the stream of vapour by a gaseous tube that restricts the ingress of oxygen and nitrogen; by affecting the metallurgical analysis of the deposit; and—perhaps most important of all—by condensing to form a jacket of slag that prevents unduly rapid cooling and consequent cracking. As the stream of metallic vapour in the arc is derived from the covering as well as from the wire, the metallurgical analysis of the deposit is controlled by both sources. In structural welds, the deposit usually contains only 0·08 per cent. to 0·10 per cent. of carbon—values that are low but sufficient. It is a fallacy to assume that higher carbon, giving greater tensile strength in samples cut wholly from deposited metal, is desirable for structural steels of higher tensile strengths: the ultimate and plastic strengths available with moderate or low-carbon deposits are generally so high that tensile test-pieces cut from welded joints have to be notched in the deposit to force the fracture to occur there, rather than in a

---

* The Eighth Andrew Laing Lecture, delivered at Newcastle-on-Tyne before the North-East Coast Institution of Engineers and Shipbuilders, on Friday, November 10, 1939. Abridged.

remote section through the plates. The fundamental requirement for obtaining high tensile-test figures in welded joints is not generally a deposit of greater strength, but rather of greater ductility.

Notched-bar bending tests have been widely used and are of special interest in connection with welding for three distinct reasons. (1) In times past, particularly when bare-wire electrodes were used, considerable difficulty was experienced in obtaining tough deposits free from undue oxygen and/or nitrogen; and at all times, when alloyed deposits are used, segregation occurs in each successive run when the alloying affects the melting point. The notched-bar test is of special service for revealing brittleness, because it produces severe local stresses immediately below the notch and because these stresses are commonly of the nature of "triple-tensile" stress, tending to cause brittle fracture even in metals endowed with fair degrees of ductility, as judged by other tests that produce stresses more of the nature of shear. The work of the Welding Research Committee* appointed by the Institution of Mechanical Engineers, and notably of Professor F. C. Lea and of Dr. Schuster, has shown that welds of ordinarily good quality, produced by electrodes with suitable coverings, give excellent notched-bar values over as wide a range of temperature as good structural steels. In notched-bar tests, welded and unwelded samples alike are sensitive to temperature; and all mild steels, in different degrees, tend to become brittle when the temperature falls below limits that are generally only slightly below, and may be occasionally above, zero Centigrade. The danger of hard frost has been amply confirmed by scientific investigation. It appears that notched-bar tests, if they are to be carried out at all, should be directed to ascertaining the limiting temperatures and other conditions under which steels become brittle, rather than simply to record the Izod value at any chance temperature. When the temperature varies widely, it is a common practice slightly to warm notched-bar test pieces, in a bucket of water, before they are tested.

(2) The use of arc-welding for high-tensile steel plates has brought a risk that such plates may crack internally during the later stages of cooling, on account of delayed cooling and contraction in the interior after the outer parts have hardened. Such contractions tend to induce triple-tensile stress in the interior and compressive stress in the exterior, and are peculiarly dangerous, as the internal cracking may remain undiscovered. Notched-bar tests are of special value for comparing different steels as regards suitability for welding, because the character of the stresses produced during the test has much in common with those produced by internal contractions. Hardness tests, also, are recommended for the same purpose; but they appear to be open to the criticism that limitation of hardness does not necessarily ensure freedom from cracking. Professor Ruddock and the author, in micro-examination of rivets and welds of somewhat brittle quality, have observed not only Martensite in certain samples, but also, in other samples that were slightly less hard, cracks having the characteristic profiles of the absent Martensitic grains. We are of the opinion that such cracks are formed in the less hard samples as a consequence of the local changes of volume that occur when Martensite, at low temperatures, changes to softer constituents of greater ductility.

(3) In a third direction also, notched-bar testing has contributed to the development of structural welding practice, and in a curious and almost unexpected manner: it has revealed with scientific precision sources of danger which, although recognised in practical experience, were not clearly, if at all, indicated in other mechanical tests and were, consequently, liable to be regarded as heresies. Partly on account of this, the notched-bar test has become, not only a serviceable auxiliary means of investigation, but also itself an object of scientific investigation.

The influence of size in relation to the incidence of brittle fracture is perhaps the most curious of such actions, and certainly the most important in relation to structural practice. When heavy stem or stern forgings or castings are surveyed after ships have suffered slight injuries after collision, it is not unusual to find that large parts have broken in a brittle manner, although bent only slightly. Practical men have long been convinced that large pieces may be brittle in character, although small notched-bar or other test pieces, cut from the same members, commonly give excellent results, bending far before breaking with satisfactory Izod figures. The contrast between the fractures of larger and smaller pieces of the same steel is often held to prove that flaws must have been present in the larger pieces, but that conclusion is seldom just: more commonly, the difference should be ascribed to the influence of size, and size alone.

In order to investigate this point, a large bar of specially-toughened mild steel was kindly supplied some years ago by the late Sir Henry Fowler, and tested at Greenwich by Dr. J. G. Docherty.* The initial section of the machined bar was 100 mm. square, and after it had been notched and tested, it was cut down for successive tests to smaller sections of 50 mm., 20 mm. and 10 mm. square. The notch used for the 10-mm. size was of the standard Izod profile, 2 mm. in depth, and the notches for the larger pieces were larger in proportion—the greatest care being observed to maintain precise geometrical similarity not only in this respect but also in the arrangements for supporting and loading the pieces of different sizes. The pieces were tested by slow bending in ordinary testing machines, and it was found that the standard 10-mm. sample broke in the ductile manner that might be expected in a mild steel of toughened quality, bending through a large angle before it eventually tore apart in the characteristic "horned" form of fracture. The larger pieces broke in more brittle manner, cracking suddenly after bending through angles that were smaller in the larger than in the smaller sizes. The largest sample bent through only a very small angle before it cracked violently in a manner that revealed extreme brittleness, surpassed in structural steels only when still larger pieces have been broken in subsequent studies. The results published by Dr. Docherty are illustrated in Table I.

TABLE I.

| | Mm. | Mm. | Mm. | Mm. |
|---|---|---|---|---|
| Size of square .. .. | 100 | 50 | 20 | 10 |
| Depth of notch .. .. | 20 | 10 | 4 | 2 |
| Angle bent to fracture .. | 8 deg. | 14 deg. | 38 deg. | >50 deg. |

The practical observation confirmed by this investigation, and equally by further tests on other samples, is of far-reaching importance: Large notched bars are necessarily brittle, even at ordinary temperatures, no matter how toughly ductile the metal may appear when tested in standard small-sized pieces. The danger of cracking arises even in the toughest of steels when the size exceeds certain limiting dimensions, and the determination of these safe limits for different steels appears to be a matter of considerable importance.

The practical lesson drawn from such investigations is that it is desirable to avoid, in structures that are liable to be even slightly deformed by collision or excessive static loads, the use of heavy forgings or castings, or even heavy plates, exceeding the limiting thickness for ductile bending. The remedy for brittle fracture in such parts is not the use of still heavier sections—which would prove only more brittle—but the use of lighter plates and rolled sections in a composite structure. This lesson has been applied with conspicuous success in naval architecture and in general structural practice; thus the welded bow-construction described† by Mr. C. E. Sherwin, R.C.N.C., affords an early example of methods that may be expected to be applied more widely in future. Other advantages of the "soft-nosed" ship have long been advocated by Mr. E. F. Spanner, R.C.N.C. (ret.): vessels without rigid stem forgings are less likely to injure other vessels in collision.

Although the fundamental reason for the difference between the behaviours of larger and smaller notched bars remains unknown, much has been learned in efforts to discover that secret: and some part is of practical interest in welding, as many welds are located at corners and are thereby subjected to severe concentrations of stress.

Fig. 1, photographs (*a*), (*b*) and (*c*), opposite, illustrate three successive stages of a test carried out in 1936 by Lieuts. T. G. Barber and W. Summers, and illustrate the distribution of plastic strain relatively to the notch and to the face of the fracture which, at a later stage that is not illustrated, formed on the plane of symmetry above the notch in the middle of the span. The bar was of mild steel, 50 mm. square, and the notch was 10-mm. deep and geometrically similar to the standard Izod. One side of the machined bar had been coated with a thin layer of resin, to reveal the distribution of plastic strain in the metal.

The first photograph, (*a*), shows how plastic strain commenced immediately above the notch, and forthwith spread around two curved surfaces, with the consequence that the two undisturbed ends of the beam were enabled to slide round the nearly undisturbed mid-part between the loading point and the notch. The second, (*b*), shows how the same process repeats itself on successive curved surfaces, and while further plastic strain develops on planes perpendicular to the curved surfaces. It will be understood that the layers described above as "planes" are actually of considerable thickness, comprising great numbers of crystal grains; and it is interesting to note that their directions are intimately related to the displacements, strains and stresses in the test piece and are not even distantly related to the orientations of the grains in the crystalline metal. Shear occurs also on other planes, not illustrated in the views selected, and, as a consequence, the nearly plane lenticular sides of the mid-part between the curved surfaces tilts gradually during the test, inwards on the tension side immediately above the notch and outwards on the compression side below the loading point.

The metal between the notch and the neutral axis is subject to longitudinal tension and also to tensions in the vertical and transverse directions; in fact, to triple-tensile stress. The lateral tensions tend to check the development of plastic shear strain by the longitudinal stress, which proceeds to mount up to greater values until eventually it results in the formation of a crack on the plane of symmetry, immediately above the notch. Fig. 2, opposite, shows the face of the fracture of a still larger mild-steel bar, of 6½-in. square section, and is of special interest as it shows clearly that the crack did not start from the notch but in the zone adjacent to it, subject to triple-tensile stress. The bottom of the notch is fissured in such larger pieces as in smaller, but in the larger bars the fissures at the bottom of the notches do not communicate with the brittle crack that separates the bar into two pieces.

The diagrams, Fig. 3, page 24, refer to a special form of notched-plate test devised with two aims: the first, practical—to study cracking in butt-welded seams—and the second, theoretical. This special test was used in an investigation by Mr. H. J. Tabb, R.C.N.C.* The test pieces, as shown in Fig. 3, are in the form of discs 2 in. in diameter, trepanned from the plates and drilled, milled and sawn to the profile illustrated. The discs are fitted into levers as shown, and pulled apart in a tensile-testing machine, the load being measured and plotted against the deflection of the levers. Fig. 3 also illustrates the forms of the load-deflection graphs obtained in different typical examples. Tough samples yield in a plastic manner and eventually tear apart with fractures of the "horned" type that is familiar in similar metals in the Izod test, and more brittle samples break by cracking in earlier stages after lesser degrees of plastic strain. Test pieces cut from unwelded plates give different results according to the direction of rolling, relatively to the tested radius of the disc; and welded pieces, tested with the centre-line of the weld along the test radius, give results that are usually as good as those obtained with rolled plates broken along the direction of rolling. Brittle welds snap readily, but soft mild welds of inferior qualities, containing quantities of slag and numerous gas bells, commonly reveal surprising toughness and leave the impression that these faults may be not as dangerous as we often assume.

The special form of the notched-disc test piece offers the theoretical attraction that the stresses acting in the vicinity of the test radius can be calculated with mathematical precision in two distinct ways: (1) by means of an elegant classical analysis due to Professor C. E. Inglis† firmly based upon the principles of equilibrium and elasticity and applicable up to (but not beyond) the limit of elasticity of the test piece; and (2) by means of a simpler formula that is readily derived from the principles of equilibrium and plasticity, and is applicable only when the metal is yielding in plastic manner all across the test radius of the sample.

In applying the first method of calculation, the load adopted as the basis of calculation was the relatively small value at which plastic strain was observed to commence immediately behind the notch. This relatively small load gives high stress on account of the severe concentration caused by the notch with its very sharp radius of curvature. In applying the second method, the basic load used was the greater value at which plastic strain developed rapidly across the test radius without further increase of load. This greater load gives lower stress values, as the initially severe local concentration of stress has now been dissipated by the development of plastic strain. It is believed that no other form of notched piece offers the same opportunities for making direct comparisons between the results of notched-bar and tensile tests; the results are, therefore, of special interest from the theoretical point of view, and are quoted in Table II, on the opposite page, in tons per square inch.

Two very notable conclusions can be drawn from these figures: (1) The stresses required to start plastic yield in mild steel "as rolled"—or normalised—are remarkably high, being, in fact, greater than the ultimate tensile strength. These high values are of scientific interest only—corresponding to the "higher yield points" that can be determined in tensile tests when suitable precautions are observed to ensure that the stresses do not even locally exceed the nominal values given by the simple formula $f = \frac{F}{A}$. They serve

* Third Report of the Welding Research Committee. *Proc.I.Mech.E.*, vol. 140, page 521 (1938).

* See ENGINEERING, vol. 139, pages 211 and 285 (1935).
† *Trans. I.N.A.*, vol. lxxviii, page 247 (1936).

* *Ibid.*, vol. lxxvii, page 193 (1935).
† *Ibid.*, vol. lxiv, page 253 (1922).

to explain results that otherwise might appear anomalous; for example, how weld deposits appear to be so little affected by the presence of air-bells and slag inclusions, or even cracks, all of which must produce severe concentrations of stress. It appears that high stresses do not produce plastic strain provided that they are kept just within, and are not allowed quite to reach the "higher yield point"; but if or when plastic strain is once produced in the metal, it cannot again withstand (without yielding further in the plastic manner) any stress exceeding the "lower yield point."

TABLE II.

| Sample Number. | O. | I.A. | I.C. | II.A. | II.C. |
|---|---|---|---|---|---|
| (1) Elastic limit, calculated from the load at which plastic strain was observed to start .. .. | 16·2 | 35·6 | 32·3 | 37·5 | 35·8 |
| (2) Yielding stress, calculated from the greater load at which plastic strain was observed to be spreading.. .. .. | 16·8 | 18·5 | 17·4 | 20·3 | 19·4 |
| Lower yield point in tensile test .. .. .. | 15·7 | 15·7 | 16·7 | 17·5 | 17·5 |
| Maximum (ultimate) in tensile test .. .. | 28·3 | 26·5 | 27·8 | 29·5 | 29·6 |

Samples I and II were cut from structural steel plates "as rolled," while sample O was cut from a strained plate that had cracked in a vessel that had broken her back on a sandbank. Samples A were tested along the direction of rolling, and samples C across.

Sample O, for example, cut from a plate that had cracked and yielded in a vessel that had broken in two across a sandbank, yielded in the notched-disc test when the stress calculated by Professor Inglis' formula reached 16·2 tons per square inch, a value that only slightly exceeds the lower yield point, determined at 15·7 in an ordinary tensile test. (2) When the limiting load on the notched-disc test piece, for general spreading of plastic yield revealed by rapid increase of deflection without increase of load, is calculated from the tensile lower yield point as a basis, by means of an appropriate formula, it agrees closely with the tested value. The figures tabulated indicate that the tested loads slightly exceeded the calculated values, which are, therefore, slightly on the safe side; but the calculated stresses would have been somewhat lower, and the margin slightly less, if one or other of the strain-energy functions, based on thermodynamic considerations, had been used instead of Guest's Law in order to make the calculation.

In the second of these conclusions, we have a first example of a far-reaching principle of structural design —that the limiting conditions governing the incidence of plastic strain in structural members, even of complex shape, can be calculated by using relatively simple formulæ based on the theory of plasticity and on the tensile "lower" yield point of the steel. At this stage, therefore, it may be desirable to explain first, why, and, second, how, the lower yield point is actually determined in the course of an ordinary tensile test.

When a test piece is pulled in an ordinary tensile-testing machine, the maximum or "ultimate" strength can be determined very readily; its value varies with the rate of straining, and affords an indication of the general quality of the sample. It does not afford a fully satisfactory basis for economical design, because different steels, having equal ultimates, commonly yield in different ways at different lower stresses. To overcome this difficulty, direct measurement of the elastic limit, or of the yield point defined by standard specification, is often recommended; but it is found that the value is liable to vary from 40 per cent. to 120 per cent. of the ultimate, even in samples cut from adjacent parts of the same plate. It should be added to this that the lower values, from 40 per cent. to 50 per cent. of the ultimate, are found only when the test is carried out in a rough-and-ready way without undue care; while the higher values, from 80 per cent. to 120 per cent., are found only when special precautions are taken to ensure that the stress produced in the test piece is really no more than the nominal value given by the formula $f = \frac{F}{A}$. The "lower" yield point has been introduced, specified and employed in practical design, because it overcomes this uncertainty and provides a more reliable basis of design.

It is measured as follows:—After plastic strain has started, at a load that may be disregarded as it affords only a misleading impression of the strength of a structural steel tested under ordinary conditions in a proving house, and before plastic strain has spread along the whole length of the parallel portion of the test-piece, the load is readjusted (being raised or lowered, as necessary) to re-balance the beam of the machine while plastic strain continues to spread slowly and steadily along the length of the test-piece. This load, F, divided by the cross-sectional area, A, gives the lower yield point $y = \frac{F}{A}$. The value varies slightly according to the rate of straining employed, but not more than does the ultimate tensile strength; and it is often found to vary perceptibly between the different ends of one and the same sample—for not all plates are of ideally uniform quality. The measurement of the lower yield point often affords a serviceable indication of such variations, *e.g.*, when one end of a normalised sample has cooled more slowly than the other. The value of the lower yield point commonly ranges from under 50 per cent. to just over 70 per cent. of the ultimate; so that, when steel of the higher ratio is used in designs based on the expectation of the lower ratio, the waste of metal is of the order of 40 per cent.

The determination of the lower yield point presents no difficulty if the operator grasps the idea that he is expected to re-balance the beam after plastic strain has started and before the whole of the metal in the length of the test piece has been strained and thereby hardened. The opportunity for thus re-balancing continues quite long enough for the measurement, when the rate of straining is slowed down to a suitable rate so that the gradual development of strain can be watched. During the process, the mill-scale is seen to be flaking off one end first and then off other parts; the value of the lower yield point cannot be read after the process of flaking has spread along the whole length of the piece.

The word "lower" is used in describing this characteristic yield point, at which plastic strain—once it has been started—continues to spread through the metal to produce effects corresponding to failure, because a distinction is required from the so-called "higher" yield point, which might be called the "true" elastic limit of the steel. The higher value, which is of very little, if any, practical importance at present—but of great academic interest—has been investigated very thoroughly at Greenwich, particularly by Dr. J. G. Docherty and Mr. F. W. Thorne.* Samples of ordinary structural steel, normalised or in the "as rolled" condition and free from plastic strain, were shown to stand quite extraordinary stresses elastically when precautions were taken in tensile tests to ensure that the stresses were accurately calculated by the simple formula $f = \frac{F}{A}$, which, of course, is truly applicable only under favourable conditions. By using streamline profiles without shoulders or collars, by avoiding the use of centre-punch marks, and by using special grips to ensure axial loading without bending moments, Dr. Docherty and Mr. Thorne established beyond doubt the interesting fact that structural steels free from plastic strain will actually behave elastically up to stresses approaching or even exceeding the tensile ultimate before they begin to suffer plastic strain. These great stresses can be applied repeatedly or for long times provided that they are not exceeded. In practice, of course, plastic strain starts under much smaller nominal stresses, because the nominal values are greatly exceeded on account of stress-concentrations caused by local changes of profile or even by centre-punch marks or petty roughnesses. Therefore, we can never rely on the higher yield point at which strain starts locally, but must restrict ourselves to the lower yield point, at which plastic strain spreads through the metal in a dangerous manner, leading to the collapse of the structure. If any important member of a real structure were actually loaded to the higher yield point, without yielding, any slight quiver would lead to its immediate and complete collapse.

To illustrate the significance of the lower yield point as a basis of calculation, and of the theory of plastic as distinct from elastic failure, the diagrams shown in Fig. 4, on page 24, refer to tests carried out at Greenwich by Const.-Lieut. L. Kirkpatrick and by Mr. I-S. Sing, who used "four-point" loading to produce nearly uniform distributions of bending moment in all sections through the full length of butt-welds or along the mid-part of unwelded test pieces. The value of this bending moment—at least for small angles of bending—is given by

$$M = \tfrac{1}{2} F (L - \mu T),$$

and is thus, unfortunately, affected by the coefficient of friction $\mu$ and by the thickness of the plate. In the case cited, the term $\mu T$ is estimated to be about 10 per cent. of L; and allowance has been made for this in plotting the reference loads $F_e$ and $F_p$ in the diagram.

The value of the limiting bending moment for such a test piece, of rectangular section, can be calculated in terms of the lower yield point by two distinct methods based on different ideas as to how the stress is distributed across sections—as indicated in the diagram. According to the familiar formula based on the principle of equilibrium and elasticity, the stress distribution graph is a straight line, and the limiting value of the bending moment is given by

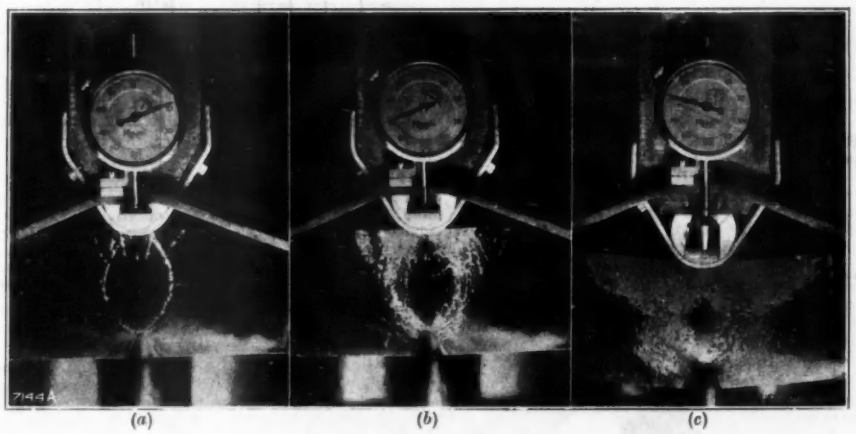
$$M = B \cdot T^2 \cdot \frac{y}{6}.$$

But, according to the principles of equilibrium and plasticity, the distribution of stress is a double rectangle —indicating that all parts above the neutral axis are simultaneously yielding in tension while all parts below that axis are yielding in compression. The modified distribution of stress gives a different formula for the limiting bending moment in terms of the same limiting stress, y; thus

$$M = B \cdot T^2 \cdot \frac{y}{4}.$$

In the case of the rectangular section, the limiting value is just 50 per cent. greater for the plastic distribution than for the elastic; but the difference is not as marked for the rolled sections in general use in structural practice.

The results plotted in Fig. 4 throw useful light on the answer to the query, "which of these two limiting bending moments is the more serviceable as a guide in practical design?" The loads corresponding to




(a) (b) (c)

FIG. 1.

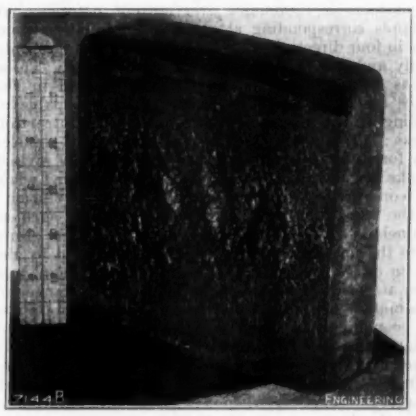



FIG. 2.

* See ENGINEERING, vol. 132, page 295 (1931).

the two methods of calculation have been marked on the scale of ordinates; and it is quite clear that, although small plastic strains may be observed when the load exceeds the lower value corresponding to the familiar elastic formula, the load at which calamitous plastic strain spreads in a dangerous manner and attracts attention without the use of sensitive extensometers or other scientific instruments is very closely in agreement with the value indicated by the plastic theory of failure.

The use of the first formula, with interesting modifications taking account of the influence of the higher yield point, is of great scientific interest, but cannot now be recommended for the continued use of practical designers who may desire to know the conditions under which their structures will actually collapse when overloaded. The second method of calculating the limiting bending moment affords a more reliable basis for judgment, and can be used with a rational "factor" to ensure an appropriate margin for real safety. The distinction may have been of little import when riveted joints were used exclusively; but it is now becoming a matter of direct economical importance, since arc-welding provides a means of making the joints at least as strong as the rolled sections. It is believed that the best structural practice of the future—as of to-day—will be based on two steps:—(1) Design the rolled section or composite so that its strength, reckoned by the plastic theory of bending, provides a reasonable margin over overload requirements; (2) design the welded joint to provide the full strength of the rolled or composite sections to be joined.

The adoption of the foregoing method of design results in considerable economies over current practice, but demands corresponding attention to details—particularly in four directions that will be mentioned now only briefly and will be developed in greater detail. These are as follow:—(1) The structural steel used in the plates and sections must be of a quality capable of welding in a reliable manner, without contraction cracks; (2) the method of design suggested suffices only for static loading, and must be drastically revised to take account of the danger of fatigue cracking when the conditions of service include severe vibration; (3) the use of unsymmetrical rolled sections such as channels is to be avoided, because they do not stand up to the limiting bending moments calculated by the plastic or even by the elastic method of design, and more attention will have to be given to the danger of instability when scantlings are reduced to obtain the full economic advantages of arc-welding; (4) current designs will have often to be modified fundamentally to keep static deflections within tolerable limits, and to maintain frequencies of natural vibration high enough to avoid resonance, when scantlings are reduced to allow the higher nominal stresses appropriate to the use of stronger steels with stronger joints.

In structural steels of ordinary trade qualities, the value of the lower yield point is usually not less than 60 per cent. of the ultimate, although few steelmakers even to-day are willing to guarantee more than 50 per cent.: the value of the ratio is apparently affected by the proportion of manganese present. In steels of 28 to 30 tons ultimate, that are readily arc-welded, a lower yield point of 17 tons per square inch can be expected in "as rolled" plates; and values to about 21 tons per square inch are available in plates of higher tensile strength, although these are not always free from contraction cracking when riveted or welded. It has long been general practice to use milder rivets in high-tensile plates; and, for similar reasons, mild electrodes suffice, and are desirable, for welds between high-tensile plates.

To indicate what can be accomplished in welding high-tensile plates, it is proposed to give figures for tensile, bending and fatigue tests on samples cut from one of the silicon-steel plates of the earlier Mauretania. The original suggestion, that one of the high-tensile plates of this famous vessel should be re-investigated after so many years of successful service on the western ocean, was due to my colleague, Mr. C. H. Helmer; and the plate was kindly supplied by Messrs. Metal Industries, Limited. It is believed that the results will be of interest wherever high-tensile steel is being welded, for it may be recalled that the use of high-tensile silicon steel was a notable feature in the Mauretania, and that the vessel continued immune from difficulties experienced by others in comparable service. The analysis of the particular plate tested was found to be as follows: C, 0·31; Mn, 0·79, Si, 0·83; S, 0·025; P, 0·040. The carbon and manganese are high enough to raise doubts as to the reliable "weldability" of the steel, while the high silicon is a feature that has fallen out of fashion and is not at present regarded as favourable to arc-welding.

The tensile figures for a sample cut from the plate as received, without heat treatment, are given in Table III. The lower yield point is almost exactly 60 per cent. of the ultimate and approximately 25 per cent. higher than in 28 to 30-ton steel, although the actual stress on the ductile fracture is not much higher than in other steels. The numerical sum of the ultimate and the elongation in tons per square inch and per cent., respectively,

TABLE III.

| | | |
|---|---|---|
| Lower yield point | ...tons per sq. in. | 21·0 |
| Ultimate tensile strength | ,, | 33·2 |
| Actual stress caused by reduced load on reduced cross-section at fracture ... ... | ,, | 63·7 |
| Reduction of area at fracture, per cent. | | 59·3 |
| Elongation formula, for cylindrical test pieces ... ... | ,, | $17\cdot9+119\left(\frac{d}{l}\right)$ |
| Elongation on 8 in. ... ... | ,, | 24 |

comes out at 57, which is regarded as a satisfactory value.

The plate was cut into four parts, and three of these were sub-divided and welded by three different processes in general use. Two were welded by hand, with different seams, currents and electrodes; while the third was welded by the "Unionmelt" process and gave quite phenomenal results in bending tests and in fatigue. All the samples tested in bending and in fatigue were of the full thickness of the $\frac{7}{8}$-in., 35-lb. plate, but the excess metal deposited in welding was trimmed off and the surfaces of the welds were roughly ground in the manner that is customary for boiler-making. The surfaces were not fine-ground or polished, and it is believed that the figures obtained can be regarded, therefore, as representative of what may be expected in practice, rather than of special laboratory tests intended to give the highest figures possible for the metal.

The results of early stages of the "four-point loading" bending tests are plotted in the four graphs of Fig. 4, above; and their wider significance, in relation to the theory of plastic bending, has already been discussed. It is clear that the limiting working strengths are nearly alike in the four samples, that the deposits have been suitable for the high-tensile steel, and that the same calculations for strength are equally valid for the welded and for the unwelded samples. The results of the later stage of the bending tests are shown in Fig. 5, on this page. After being bent in the earlier test, the pieces were bent further by end loads and two were finally pressed flat by lateral loads. The unwelded sample, and also the Unionmelt weld, survived this treatment without any sign of cracking; and the machined edges of the welded sample revealed only the faintest indication of the location of the weld. The two hand-welded samples made with different electrodes show fissures on the outer surfaces at different degrees of bending. The weld that shows cracks at the smaller angle of bending was of double-Vee type, deposited with 140-180 amperes; while the other was of single-Vee type, wider, and deposited with currents ranging from 100 amperes to 280 amperes. The currents used for the two runs in the Unionmelt weld were 900 amperes and 1,300 amperes. The cracked and bent fatigue-test piece, with screwed ends, shown in the same photograph, illustrates the remarkable toughness of this silicon steel ex Mauretania. This fatigue piece, electrically-welded by hand with Vee seam, and cracked during its fatigue test, was bent open afterwards by hammer. Instead of breaking from the bottom of the notch formed by the fatigue crack, it bent open gradually in the most ductile manner. This result is unusual, and the fact that the cracked pieces bent in such a ductile manner is regarded as high testimony of the capacity of the steel for welding without injury.

The scientific term "fatigue" may be ill-chosen on account of some of its implications; but it signifies no more—and no less—than the effects of "working" or vibration. It may be recalled that Andrew Laing was engaged almost continuously in active conflict with vibration. In the gradual evolution of his engines, from the three-crank compounds of 1884 in Umbria and Etruria, and the five-cylinder three-cranks of 1892

Fig. 3.

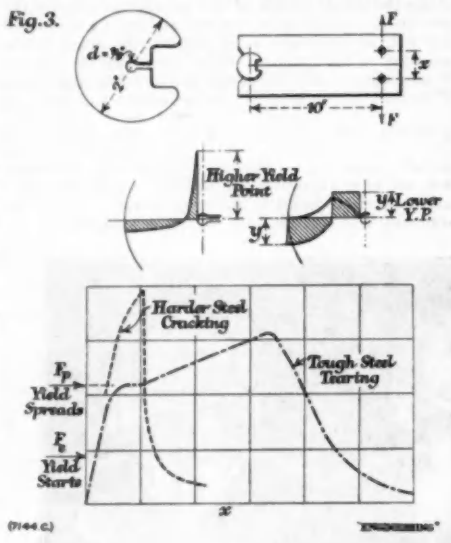
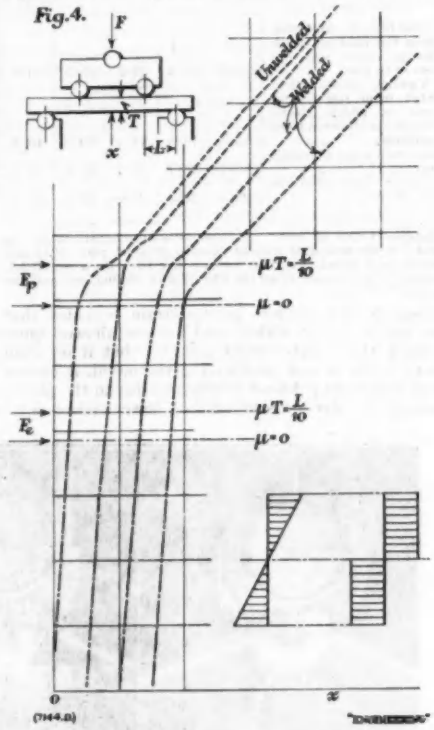



Fig. 4.



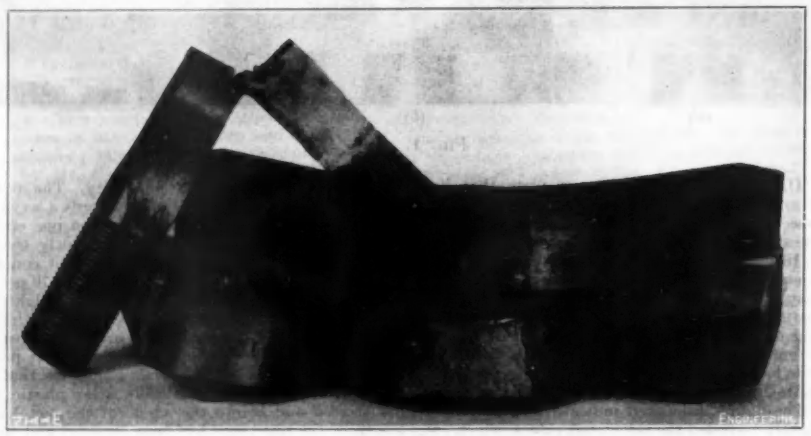
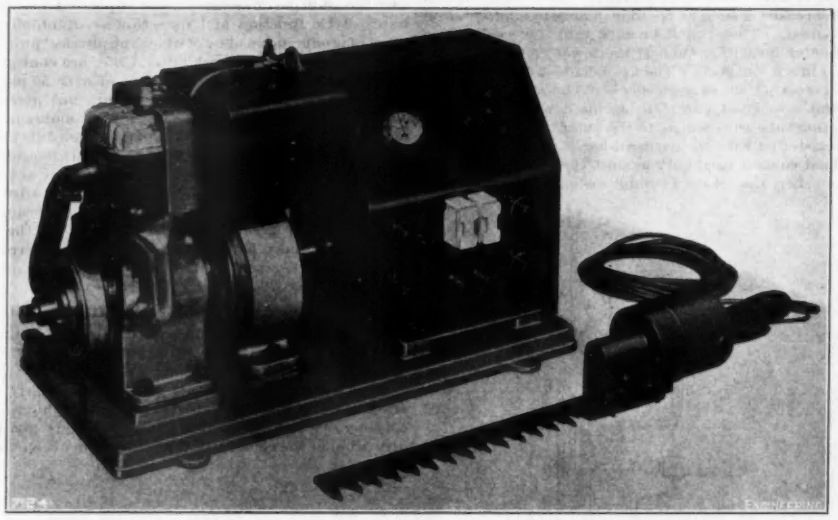



FIG. 5.

FIG. 5.

# PORTABLE GENERATING PLANT.

MESSRS. BRADBY'S ENGINEERING WORKS, LIMITED, LONDON.



in Campania and Lucania, to the four-crank quadruples of 1899 in Ivernia, we may recognise not only continuous progress in economy of steam but also successful conflict with vibration and fatigue. Although the conflict may have appeared for a time to have been closed in 1906 with the introduction of the direct-drive turbine machinery in Mauretania, it was not really so; and it was definitely re-opened in 1912 with the advent of internal-combustion engines in Abelia. Those who, to-day, maintain the same conflict appreciate more clearly the importance of corrosion-fatigue, and doubtless more clearly appreciate also that dynamic balancing in engines does not necessarily reduce the cyclic stresses in engine parts. The action of fatigue is cumulative: except when it is annealed before a crack has even started, metal never forgets what has happened in its past: a few cycles of unduly severe stress on one voyage followed by a few more on another, gradually mount up to cause fracture after a relatively small total number of such cycles. On the other hand, a number of cycles of stresses approaching, but not exceeding, the limiting safe value, tend apparently to raise the value of the safe limit for subsequent loadings, and it is probable that this effect—known as "understressing"—is distinctly beneficial in ordinary practice.

When fatigue-cracking occurs in the hull of a vessel subject to engine or propeller vibration, it is commonly attributable to "corrosion-fatigue"—that strange conjoint chemical and mechanical action that leads to cracking after great numbers of cycles of even small stresses. Corrosion-fatigue was first discovered at Greenwich nearly twenty-five years ago.*† In 1926, it was independently rediscovered by Dr. D. J. MacAdam, of the United States Naval Experimental Station at Annapolis, Maryland. The simultaneous action of corrosion and fatigue is dangerous in the extreme when prolonged. The significance of the word "prolonged" differs in different cases, for the accumulation of, say, 100 million cycles is rapid when the frequency of vibration is fast. It may be largely due to this cause that high-frequency vibrations were formerly believed to be more dangerous than slower. Twenty-five years ago, it was discovered at Greenwich that the danger of corrosion-fatigue may be mitigated, in steel, by coating the steel with a layer of zinc applied by the familiar process of "hot-galvanising," which checks the electrolytic action on which the action appears to depend; and subsequent investigations in America by Speller and Munn showed that the action could be inhibited by using bichromate of potash or other substances in solution in the water. Ordinary fresh water and distilled water appear to be less dangerous than salt.

*(To be continued.)*

THE AMERICAN COLLIERY INDUSTRY.—The production of bituminous coal in the United States averaged 1,427,000 tons per day during the week ending December 16, 1939, compared with 1,470,000 tons in the previous week and 1,352,000 tons in the corresponding week of 1938.

* *Jl. Inst. Metals* (1917).

† *Trans. Inst. Chem. Engineers*, vol. 7 (1929).

## PORTABLE GENERATING AND PUMPING PLANT.

ALTHOUGH the accompanying illustration shows a compact portable electric-generating set only, it will be inferred from the title of this account that a portable pumping set on the same general lines is available. The sets are made at the works, at Ditchling, Sussex, of Messrs. Bradby's Engineering Works, Limited, 41, Rylett-crescent, London, W.12, and are identified by the title "A.M." type Pygmylyte portable electric generator or pumping plant, as the case may be. Dealing first with the generating set, as shown in the illustration, it will be seen that the whole unit is mounted on a common baseplate. This is of aluminium and has a carrying handle at each end. The overall dimensions are 22 in. long by 11 in. wide. The dynamo, contained in the case to the right, has an output of 360 watts at 12/15 volts. The spindle is mounted in ball bearings, and the windings are arranged so that in starting up the set the generator functions as a motor energised from a 12-volt battery. The actual starting is by push button. Should the battery be completely discharged, the engine can be started by a wire-rope starter operated on the end pulley.

The dynamo is direct-driven by a 1½-h.p. single-cylinder four-stroke cycle petrol engine, running at 2,500 r.p.m. The cylinder is 2 in. bore by 2 in. stroke, and has a capacity of 104 cc. As will be recognised, the engine is air cooled, a fan being embodied in the flywheel seen to the right of the engine and discharging by way of a cowl. A crankcase breather is fitted. The cylinder head and piston are of light alloy and a standard 14-mm. sparking plug is used. The patent suction-type carburettor has an adjustable throttle and choke, the throttle enabling the speed to be varied between 1,400 r.p.m. and 2,500 r.p.m. Ignition is by a flywheel magneto, an advance and retard lever, which can be locked for the desired continuous running conditions, being provided. The petrol consumption at full load is 0·67 pint per hour. The 0·5-gallon fuel tank is situated above the flywheel fan casing. The normal fuel is petrol, but the engine can be arranged to run on paraffin or gas, if required. The crankshaft is mounted in ball bearings and all parts are splash-lubricated, the oil level being ascertained by dip stick. The lubricating-oil consumption is stated to be negligible. The generating set is intended for farms, small dwellings, air-raid shelters, or other situations in which current is not available from mains, and can be used for lighting, battery-charging, etc., in isolated situations. Alternative sets having an output of 400 watts at 24 volts or 32 volts are available.

The apparatus in the foreground of the illustration calls for some comment. It is included as an example of the multifarious uses to which the generating set can be put to on a farm and is a motor-driven hedge-trimmer. The cutting portion consists of a fixed blade and a reciprocating blade driven by the motor, both being serrated and 18 in. in length. The scissor-like cutting action will sever stems up to ¼ in. in diameter. The trimmer works at 12 volts and is driven from the generator set and the 12-volt battery. The current consumption is 7·5 amperes. The utility of the trimmer may be estimated from the fact that a test showed it to be capable of cutting a section of a yew hedge in 20 minutes, a section of similar area taking a man four hours to cut with hand shears.

The construction of the pumping set now calls for attention. The pump normally supplied is of the self-priming centrifugal type direct-coupled to the engine, which is then set to run at from 1,500 r.p.m. to 1,700 r.p.m. The output is 400 gallons per hour with a total head of 60 ft. The suction and delivery pipes are 1 in. in diameter. The set has the same size of engine as has the generating set, the two being mounted on a common aluminium base plate, and the complete unit weighing 70 lb. In cases where the generating set is employed, and where pumping is also called for, a likely contingency in isolated areas, the engine of the generating set can be readily uncoupled and connected to the pump, one engine thus serving two purposes. Alternatively, the two units can be supplied in a permanent combination with a single engine, this set then consisting of a generator set for lighting purposes, a 12-volt battery, and a centrifugal pump. A separate ½-h.p. motor mounted on a wooden base for the hedge trimmer, also included, completes the outfit.

## THE CLASSIFICATION OF COMMERCIAL COPPERS.

BOTH users and producers of copper have long felt the need for a more rational classification of the different grades of the metal than has hitherto obtained, for the terms commonly used, such as "Best select," "Fine," "Tough," and so forth, have no value as definitions, and, moreover, are capable of widely-differing interpretations even among producers, who might have been supposed to have agreed to more or less unvarying standards between themselves. The Ministry of Supply has, however, recently issued a paper entitled "Control of Non-Ferrous Metals (No. 5) Order, 1939," which includes a classification of commercial copper. This classification, although it is neither as complete or as definite as it might be, nevertheless shows evidence of a praiseworthy attempt to place the grading of copper on a more logical and scientific basis, and as such may well form a foundation for further clarification. To this end criticism will be useful, provided it is constructive and the critics are content to accept the tentative classification now put forward until the country and industry return to peace conditions.

In such a spirit are some comments on the "Order" by the Copper Development Association, Thames House, Millbank, London, S.W.1. The Association holds the view that, presumably, the new classification is a compromise based on many conflicting factors which it is necessary to take into account to meet the present abnormalities in industry and to interfere as little as possible with established commercial practice. It will also be appreciated, the comments continue, that in the present circumstances sources of supply are necessarily limited and that, in consequence, certain brands of metal may be no longer available. Little difficulty should be experienced, however, in obtaining suitable substitutes from sources within the British Empire. The new classification is, briefly, as follows: (1) High conductivity electrolytic copper; (2) fire-refined copper sold, or intended to be sold, as high-conductivity copper; (3) high-grade fire-refined copper; (4) fire-refined copper of ordinary quality containing not less than 99·7 per cent. of copper; (5) fire-refined copper containing not less than 99·2 per cent. of copper; and (6) black hot-rolled copper wire-rods.

The Copper Development Association holds the view that copper of Grade 1 and Grade 2 will conform to the recognised standards for high-conductivity metal, and that these grades, and also Grade 4, Grade 5 and Grade 6, do not call for detailed comment at the present time. In the case of Grade 3, however, it is pointed out that no information is given as to what the expression "High-Grade Fire-Refined Copper" is intended to cover. At the same time, it is evident that it is designed to include that large category of first-quality fire-refined copper, much of which has in the past originated from Chilean, and, more recently, from African sources, such brands as C.F.R., Braden, M.T.D., B.C.R., and E.R.M. being examples. In nearly all cases the minimum copper content of this grade would be approximately the same as that of the high conductivity grades, *i.e.*, about 99·88 per cent., although the metal might not always be suitable for electrical purposes requiring the highest conductivity. While the classification is based primarily on conductivity and copper content, and indirectly on impurities, provision has been made to include also certain categories of copper containing very small amounts of such constituents as arsenic and cadmium. For the purposes of classification, such specified contents are to be counted as copper. For example, arsenical copper containing over 99·3 per cent. of copper and nominally 0·4 per cent. of arsenic would not be classed as Grade 5, but as either arsenical Grade 3 or Grade 4, according to its combined copper and arsenic content.

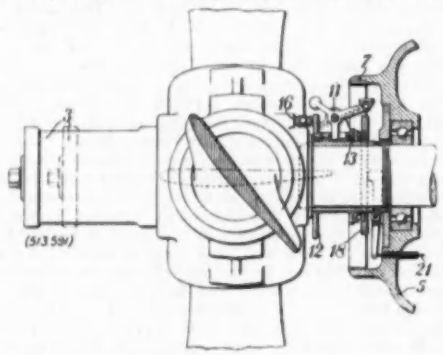
## "ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

*The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.*
*Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.*
*Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.*
*The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.*
*Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.*

### AERONAUTICS.

**513,591. Variable-Pitch Airscrew Brake. The De Havilland Aircraft Company, Limited, of Hatfield Aerodrome, and F. M. Thomas, of Hatfield.** (2 *Figs.*) April 6, 1938.—The invention is a brake for a variable-pitch airscrew which is automatically applied when the blades are feathered. From the front of the airscrew hub extends a sliding cylinder 3, and the casing 5 is extended to form a fixed brake drum 7. A sleeve fixed on the shaft carries three pairs of lugs, each supporting a three-armed lever 11, one arm of which carries a brake shoe. Two rings 12, 13, rigidly connected by rods, slide on the sleeve but




do not rotate round it. Slots in the rods receive the tails of the levers 11, which are tied to the lugs by a snap-action spring. Rods 16, which slide within the hub, are connected to the cylinder 3 and bear against the ring 12 through compression springs. A ring 18, which slides on the shaft, bears against the ring 13 and is controlled by a forked lever connected to the cockpit by a cable 21. The operation is as follows: When the pilot feathers the blades, the cylinder 3 moves to the right, and with it the rods 16. The springs push the assembly 12, 13 to the right, the levers 11 snap over dead-centre and apply the brake, which stops the airscrew and engine. When a re-start is to be made, the pilot pulls the cable 21 and moves the assembly 12, 13 to the left, releasing the brake. If the slight torque available is insufficient to start the engine, the cable is pulled farther until the rods 16 abut against the ring 12, so that the cylinder 3 is positively thrust forward and the pitch of the blades is reduced.—(*Accepted October* 17, 1939.)

### ELECTRICAL APPARATUS.

**513,851. Carbon-Arc Projector. The British Thomson-Houston Company, Limited, of London, H. Trencham, of Ruislip, and F. A. Tuck, of Harrow.** (1 *Fig.*) April 8, 1938.—The invention is a controller for a carbon-arc projector which maintains the crater on the positive carbon in the correct position. The positive carbon is automatically fed in the known way. In order to maintain the crater at a normal position, the output from a

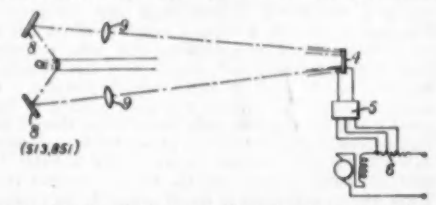
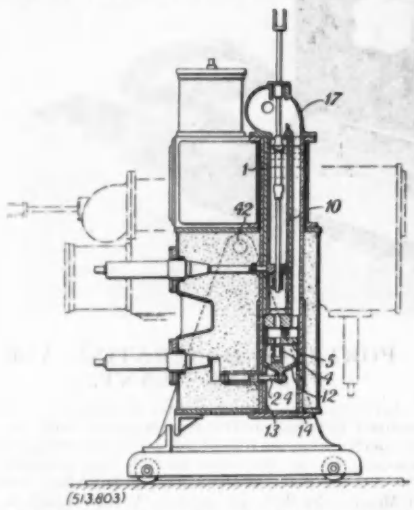



photo-electric cell 4 is passed through a speed controller 5 for the feed motor. This controller consists of a thyratron having a relay in its output circuit, which cuts in or out sections of a resistor 6 in the field winding of the motor. To control the output of the photo-electric cell, mirrors 8 and lenses 9 throw an image of the crater on to opposite edges of the cell; thus if the crater moves from its normal position at which one-half the image falls on each edge of the cell 4, the images will be deflected so that a change of illumination of the cell takes place which produces a corresponding change in the output, this, in turn, varying the speed of the feed motor. (*Accepted October* 24, 1939.)

**513,803. Oil Circuit Breaker. Metropolitan-Vickers Electrical Company, Limited, of London, and D. R. Davies, of Sale.** (3 *Figs.*) April 22, 1938.—The design of the breaker is such as to allow a small quantity of oil to be used. The circuit-breaker tank for each phase is an outer insulating tube 1, the lower end of which is housed in a metal shell. The fixed contact 4 is associated with a cross-jet arc extinguisher 5. The moving-contact rod and associated parts are enclosed within a second insulating tube 10 eccentric to the outer tube 1, the lower end registering with the extinguisher. A sleeve 13 holds the fixed contact carrier 12 against the lower end of the extinguisher, the whole assembly being clamped by end




caps 14 and 17. The contact carrier 12 is connected with the conductor through a sliding conductor rod 24 secured by nuts to a lug on the carrier. Between the inner and outer tubes is a longitudinal crescent-shaped space from the arc extinguisher to the top of the chamber 1, the lower end communicating with the extinguisher and the upper end with the cap 17. The tubes are filled with oil. In operation, when the moving contact is retracted, the arc pressure causes oil to flow laterally across the extinguisher from which it passes, together with the arc gases, upwards through the space between the tubes to the cap 17. The latter forms a vent for the gases while retaining the oil within the circuit breaker. When the fixed contact or the extinguisher require attention, it is only necessary to remove the cover-plate 14 and slide back the conductor rod 24. The sleeve 13 is then withdrawn to allow withdrawal of the contact carrier 12 and the extinguisher 5. The whole unit is mounted on a trolley and can be swung about a horizontal pivot 42.—(*Accepted October* 23, 1939.)

### MACHINE AND OTHER TOOLS, SHAFTING ETC.

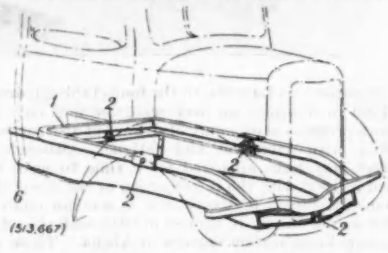
**505,667. Thrust Bearing. Coventry Gauge and Tool Company, Limited, of Coventry, S. J. Harley, of Coventry, and J. E. Wainwright, of Coventry.** (4 *Figs.*) November 23, 1937.—The invention is a thrust bearing which allows no axial movement of the spindle, and is primarily applicable to precision grinding machines for grinding screw threads. The spindle is mounted in the alternating field produced by two electromagnets and carries a laminated disc secured mid-way between the magnets, the intensity of the field of which can be varied. The coils of the magnets are connected in parallel through a resistance, one pole of the supply being connected to the junction of the coils while the other pole is connected to the sliding contact on the resistance so that variation of the resistance in one direction will reduce the current supply to one of the magnet coils and at the same time increase the supply to the other coil. For light operations the force exerted by the magnets on the laminated disc is sufficient to prevent axial movement of the spindle, but heavier operations require a fixed stop on the spindle bearing to take the thrust of the spindle in either direction in conjunction with the magnets. In an alternative form the spindle is held against a fixed stop by an electromagnet. The magnet is adjustable towards and away from the end of the spindle to vary the air gap.—(*Accepted May* 16, 1939.)

### MINING, METALLURGY, ETC.

**508,319. Electrical-Resistance Alloy. Hall and Pickles, Limited, of Manchester, J. H. Russell, of Sheffield, and A. M. C. Murphy, of Totley.** January 7, 1938.—The invention is an alloy of niobium with a nickel-chromium or nickel-chromium-iron alloy from which electrical resistance elements are made. A small niobium content of not more than 1 per cent., which has hitherto been used to control additions of calcium and render the alloy capable of being forged, has a catalytic function while in the stainless nickel-chromium steels the quantity added to prevent intergranular corrosion between 300 deg. and 900 deg. C. acts as an inhibitor. It is now claimed that the addition of niobium up to 10 per cent. has, besides its catalytic function and its action as an inhibitor, the effect of producing an alloy of which the physical properties, such as hot and cold working and life, are considerably improved. A typical alloy consists of over 50 per cent. nickel, 10 to 30 per cent. chromium, not more than 30 per cent. iron, and up to 10 per cent. niobium. The usual deoxidants are also added. The difficulty in reducing nickel-chromium alloys to wire is considerably decreased by using a specific niobium content as high as 10 per cent. The final oxide produced on the wire has a greater continuity, and a closer and more adherent texture, which greatly improve the life of the wire. The niobium may be added in the form of a ferro-alloy having a 50 per cent. to 60 per cent. niobium content. (*Accepted June* 29, 1939.)

### MOTOR ROAD VEHICLES.

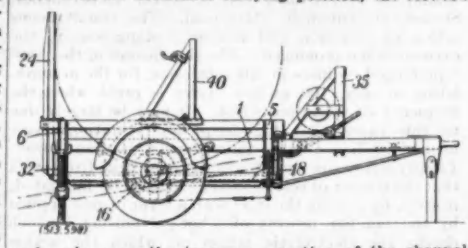
**513,667. Lorry Cab Mounting. Commer Cars, Limited, of Luton, W. Limon and A. J. Smith, of Luton.** (2 *Figs.*) April 7, 1938.—The invention is a mounting for the forward part of the bodies of lorries, particularly of the army type. When they travel over rough ground a considerable strain is thrown on to the body due to the distortion of the chassis, and the invention overcomes this




difficulty by mounting the driver's cab, scuttle, front wings and radiator upon a sub-frame 1, which rests upon the chassis 6 at four points 2 forming a parallelogram, one diagonal of which is at right angles to the other and is coincident with the longitudinal axis of the chassis. This four-point mounting is practically unaffected by distortion of the chassis and hence reduces to a minimum the risk of fracture occurring between the cab and the lorry body. (*Accepted October* 18, 1939.)

### MISCELLANEOUS.

**513,598. Cable-Drum Trailer. The Armstrong Manufacturing Company, Limited, of London, and G. M. L. Griffith, of Thames Ditton.** (3 *Figs.*) April 14, 1938.—The invention is a cable-drum trailer with a tilting floor. The trailer is two-wheeled, the axle being bent to pass under the body, which is supported by semi-elliptic leaf springs connected to the longitudinals 1. The unsprung weight is thus kept low. The floor consists of boards secured to a frame of angle-section members. The floor is mounted by lugs on a shaft 16, which is suspended from the longitudinals 1 by four triangular brackets. The tilting axis is slightly behind the middle of the floor and behind and below the axis of the wheels. When the floor is in its horizontal carrying position, the forward




end rests upon the transverse portion of the channel iron 5. When it is tilted for loading or unloading, the rear end rests upon the transverse portion of the channel iron 6, which is set lower than the channel 5. The floor is tilted by a hydraulic jack 18 on the member 5. Hinged to the rear of the floor is a platform 24, which when lowered forms an extension of the tilted floor. When the cable is being unreeled, screw jacks 32 support the rear end of the body, and a winch drum is carried in a frame 35 supported from the longitudinals 1. Frames 40 support the drum in adjustable mountings. To load a drum on to the trailer the extension platform 24 is swung down and the floor tilted by the hydraulic jack 18. The floor and platform then form a continuous slope up which the drum is hauled by the winch until its centre of gravity is in front of the tilting axis of the floor, which then tilts forwards on to the channel 5. The platform is swung up and the drum is secured by chocks with its shaft in the adjustable mountings. (*Accepted October* 17, 1939).